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Analysis of GEM-3 Data from the Advanced UXO Detection/Discrimination Technology Demonstration – U.S. Army Jefferson Proving Ground, Madison, Indiana

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Preface

The research documented in this report was performed at the Environmental Laboratory (EL), U.S. Army Engineer Research and Development Center (ERDC), Vicksburg, MS, during January through June 2001. The work involved was a part of the 62720A/AF25 program "301U-Subsurface UXO Detection and Discrimination" for Project "UXO03-Advanced Sensor Data Analysis Techniques for Improved Buried Target Detection." This research was conducted under the direct supervision of Dr. Ernesto Cespedes, Environmental Sensing Branch, EL, in support of Project UXO03.

The research was conducted and the report was compiled by Messrs. Ricky Goodson, Jay Bennett, Mses. Tere' DeMoss and Diane Cargile, Environmental Sensing Branch, and Messrs. John C.Morgan and Morris P. Fields, Illinois Institute of Technology Research Institute. Messrs. Morgan and Fields performed the analysis of the background data. The statistical analysis was performed by Ms. DeMoss. Initial Jefferson Proving Ground data analysis, tabulation, and map generation were conducted by Ms. Cargile. The discrimination analysis was performed by Messrs. Goodson and Bennett.

Dr. Ernesto Cespedes was the UXO Characterization Team Leader. Mr. Harold W. West was Chief, Environmental Systems Branch. Dr. Dave Tazik was Chief, Ecosystem Evaluation and Engineering Division, and Dr. Edwin A. Theriot was Director, EL.

At the time of publication of this report, Dr. James Houston was Director of ERDC, and COL John W. Morris III, EN, was Commander and Executive Director.

1 Introduction

This report documents the analysis of the GEM-3 data collected for the Advanced UXO Detection/Discrimination Technology Demonstration at the U.S. Army Jefferson Proving Ground (JPG), Madison, IN. The analysis is funded through the 62720A/AF25 Program "301U-Subsurface UXO Detection and Discrimination" for Project "UXO03-Advance Sensor Data Analysis Techniques for Improved Buried Target Detection." This postdemonstration analysis focuses on the evaluation of the stability of the data collected, improvements in target detection/discrimination, and positioning errors of the system.

The stability of the system is evaluated through histograms and statistical measurements of data collected during the technology demonstration. Based on findings of the characteristics of the collected data and initial work performed on target detection/discrimination (Miller et al. 2001), target detection/ discrimination techniques are applied and evaluated.

Test Site Description

The JPG test site consisted of three areas referred to as Areas 1, 2, and 3 (Cespedes 2001). Each area is 1 hectare in size and contains known targets and clutter items. The naming convention for items in the test site is the area number followed by a hyphen and the item number (i.e., item number 43 in area 3 is 3-43, item number 48 in area 2 is 2-48). The target items for Areas 1, 2, and 3 are given in Tables 1, 2, and 3, respectively. The tables list the item number followed by the location of the item in UTM zone 16 NAD 83 coordinate system (Welch and Homsey 1996). The depth of the item is measured from the top of the item to the ground surface. The UXO type, length, width, thickness, weight, azimuth, and inclination are recorded for each item. The inclination is oriented with respect to 90 deg being a nose-up position and the nose-down position is indicated by -90 deg. The item locations for each area are shown in Figures 1, 2, and 3.

The maps showing the item locations for Areas 1, 2, and 3 are shown in Figures 1, 2, and 3, respectively.

Table 1
JPG - Area 1 Target Items

Item #	Northing m	Easting m	Depth m	UXO Type	Length m	Width m	Thick m	Weight Kg	Azimuth deg	Incl. deg
1-86	4309700.512	641416.750	0.2	4.2-in. Mortar	0.52	0.105	0.105	21.9	120	45
1-88	4309684.035	641361.390	0.35	60-mm Mortar	0.182	0.058	0.008	1.05	0	0
1-90	4309679.388	641352.247	0.35	4.2-in. Mortar	0.52	0.105	0.105	22.1	270	0
1-92	4309668.548	641348.945	0.2	81-mm Mortar	0.276	0.08	0.008	2.95	30	20
1-94	4309670.663	641365.981	0.25	81-mm Mortar	0.276	0.08	0.008	2.95	75	55
1-96	4309663.286	641345.020	0.15	81-mm Mortar	0.276	0.08	0.008	2.85	330	35
1-98	4309667.056	641369.619	0.1	60-mm Mortar	0.182	0.058	0.008	1.05	275	20
1-100	4309681.176	641375.100	0.2	60-mm Mortar	0.182	0.058	0.008	1.1	195	30
1-102	4309656.291	641370.045	0.25	81-mm Mortar	0.276	0.08	0.008	2.85	210	45
1-104	4309659.265	641378.327	0.35	81-mm Mortar	0.276	0.08	0.008	2.85	180	0
1-106	4309650.172	641372.159	0.25	60-mm Mortar	0.182	0.058	0.008	1.05	75	35
1-108	4309638.289	641383.795	0.2	60-mm Mortar	0.182	0.058	0.008	1.05	100	45
1-112	4309670.570	641356.944	0.1	20-mm Projectile	0.074	0.018	0.018	100g	30	10
1-113	4309695.860	641344.701	0.5	105-mm Projectile	0.374	0.106	0.004	28.4	120	30
1-114	4309666.352	641379.460	0.15	20-mm Projectile	0.074	0.018	0.018	100g	175	20
1-115	4309686.931	641393.476	0.25	76-mm Projectile	0.498	0.076	0.006	7.6	270	30
1-116	4309660.003	641370.325	0.15	20-mm Projectile	0.074	0.018	0.018	100g	0	0
1-117	4309687.658	641422.319	0.9	152-mm Projectile	0.478	0.152	0.152	42.6	0	45
1-118	4309665.079	641410.099	0.45	5-in. Projectile	0.63	0.118	0.118	71	120	30
1-119	4309634.012	641351.264	0.4	152-mm Projectile	0.478	0.152	0.152	42.7	270	30
1-120	4309629.459	641360.225	0.25	76-mm Projectile	0.498	0.076	0.006	7.6	0	20
1-121	4309627.556	641387.439	0.5	155-mm Projectile	0.602	0.15	0.008	99.1	200	0
1-122	4309647.428	641403.828	0.91	5-in. Projectile	0.63	0.118	0.118	70.7	270	55
1-123	4309647.987	641416.776	0	20-mm Projectile	0.074	0.018	0.018	100g	--	90
1-124	4309670.579	641337.765	0	20-mm Projectile	0.074	0.018	0.018	100g	--	-90
1-126	4309671.696	641343.041	0.2	57-mm Projectile	0.118	0.054	0.004	0.8	120	30
1-128	4309662.646	641354.238	0.1	20-mm Projectile	0.074	0.018	0.018	100g	0	0
1-130	4309657.656	641350.291	0.7	5-in. Projectile	0.63	0.118	0.118	32.25	180	30
1-132	4309657.497	641359.337	0.25	57-mm Projectile	0.118	0.054	0.004	0.8	180	0
1-134	4309665.044	641374.342	0.05	20-mm Projectile	0.074	0.018	0.018	100g	120	30
1-136	4309671.569	641380.922	0.5	155-mm Projectile	0.602	0.15	0.008	45.05	90	75
1-138	4309661.180	641385.835	0.15	57-mm Projectile	0.118	0.054	0.004	0.8	95	45
1-140	4309656.690	641384.660	0.05	20-mm Projectile	0.074	0.018	0.018	100g	275	15
1-142	4309654.752	641392.730	0.15	57-mm Projectile	0.118	0.018	0.004	0.8	265	45
1-144	4309681.026	641399.341	0.5	105-mm Projectile	0.374	0.106	0.004	13	180	0
1-146	4309657.423	641400.847	0.05	20-mm Projectile	0.074	0.018	0.018	100g	270	0
1-147	4309613.119	641435.288	0.25	57-mm Projectile	0.118	0.018	0.004	0.8	0	0
1-148	4309619.590	641374.925	0.1	20-mm Projectile	0.074	0.018	0.018	100g	235	45
1-149	4309704.619	641371.539	0.5	2.75-in. Rocket	0.406	0.072	0.008	4.2	30	55
1-150	4309678.038	641341.944	0.7	2.75-in. Rocket	0.406	0.072	0.008	4.2	275	45
1-151	4309708.045	641432.206	0.25	76-mm Projectile	0.496	0.076	0.076	3.542	150	45
1-152	4309651.123	641345.675	0.15	2.75-in. Rocket	0.406	0.072	0.008	4.2	30	0
1-153	4309632.829	641426.973	0.76	2.75-in. Rocket	0.406	0.072	0.008	4.3	0	90

Note: To convert inches to meters, multiply by 0.0254.

Table 2
JPG - Area 2 Target Items

Item #	Northing m	Easting m	Depth m	UXO Type	Length m	Width m	Thick m	Weight Kg	Azimuth deg	Incl. deg
2-112	4309743.578	641696.258	0.1	81-mm Mortar	0.28	0.08	0.08	2.85	--	90
2-114	4309719.108	641679.737	0.2	81-mm Mortar	0.28	0.08	0.08	2.9	--	-90
2-116	4309707.453	641707.489	0.3	81-mm Mortar	0.275	0.08	0.08	2.85	45	0
2-118	4309700.220	641704.486	0.35	60-mm Mortar	0.18	0.06	0.06	1.19	0	45
2-120	4309688.298	641704.687	0.3	60-mm Mortar	0.18	0.06	0.06	1.15	270	0
2-122	4309692.113	641624.184	0.1	60-mm Mortar	0.18	0.06	0.06	1.16	180	30
2-124	4309683.303	641622.452	0.2	60-mm Mortar	0.18	0.06	0.06	1.12	330	10
2-126	4309674.004	641675.583	0.35	81-mm Mortar	0.27	0.08	0.08	2.85	45	45
2-128	4309687.368	641691.822	0.1	60-mm Mortar	0.182	0.06	0.08	1.13	95	20
2-130	4309671.657	641700.823	0.2	81-mm Mortar	0.274	0.08	0.08	2.8		0
2-131	4309733.931	641654.484	0.25	81-mm Mortar	0.274	0.08	0.08	2.95	0	0
2-132	4309733.468	641687.011	0.91	5-in. Projectile	0.758	0.12		31.55	90	0
2-134	4309731.276	641702.487	0.4	4.2-in. Mortar					0	0
2-136	4309707.296	641622.792	0.05	20-mm Projectile	0.074	0.02	0.02	0.1	120	10
2-138	4309708.488	641660.344	0.05	20-mm Projectile	0.074	0.02	0.02	0.1	275	15
2-140	4309704.836	641684.996	0.7	105-mm Projectile	0.262	0.105	0.105	13	330	10
2-142	4309697.175	641693.249	0.91	152-mm Projectile	0.484	0.152	0.152	19.3	300	45
2-144	4309686.347	641637.892	0.45	152-mm Projectile	0.484	0.152	0.152	19.35	50	30
2-146	4309683.272	641663.370	flush	20-mm Projectile	0.074	0.02	0.02	0.098	--	90
2-148	4309669.271	641656.726	flush	20-mm Projectile	0.074	0.02	0.02	0.098	--	-90
2-150	4309679.845	641676.348	0.1	20-mm Projectile	0.074	0.02	0.02	0.1	0	0
2-152	4309680.435	641693.918	0.25	57-mm Projectile	0.117	0.057	0.057	0.826	90	0
2-154	4309667.086	641689.383	0.2	57-mm Projectile	0.118	0.054	0.054	0.826	180	45
2-156	4309654.624	641626.571	102	155-mm Projectile	0.6	0.155	0.155	42.25	--	90
2-158	4309653.883	641647.917	0.1	20-mm Projectile	0.074	0.02	0.02	0.1	220	20
2-160	4309651.428	641691.019	0.35	57-mm Projectile	0.117	0.056	0.056	0.826	270	40
2-161	4309741.089	641627.124	0.75	155-mm Projectile	0.6	0.155	0.155	42.2	270	30
2-162	4309730.194	641669.085	0.5	76-mm Projectile	0.5	0.076	0.076	3.55	0	0
2-164	4309725.318	641622.007	0.6	2.75-in. Rocket	0.4	0.08	0.08	4.2	90	10
2-166	4309675.298	641640.848	0.75	2.75-in. Rocket	0.4	0.4	0.8	4.2	180	20

Note: To convert inches to meters, multiply by 0.0254.

Description of Data Collection Equipment

The GEM-3 is a multifrequency frequency domain electromagnetic (FDEM) system (Won et al. 1997) (Geophex 1998). The collection of multifrequency FDEM data allows for Electromagnetic Induction Spectroscopy (EMIS) of the targets and background materials (Won, Keiswetter, and Novikova 1998). The EMIS signatures are characteristic of the objects geometry and material composition and consist of complex (in-phase and quadrature) frequency responses. These EMIS signatures can provide a method to discriminate targets from natural and manmade clutter background materials. The frequencies used during the data collection were 90; 150; 330; 930; 2,790; 8,190; and 20;010 Hz. The system has been developed by Geophex Ltd. with improvements funded by the Army's SBIR Phase II program (Contract DACA39-99-C-0001) and was operated by Geophex during the JPG technology demonstration. Geophex performed the initial target detection. The initial target discrimination was performed by AETC Inc.

Table 3
JPG - Area 3 Target Items

Item #	Northing m	Easting m	Depth m	UXO Type	Length m	Width m	Thick m	Weight Kg	Azimuth deg	Incl. deg
3-68	4309868.372	641625.085	0.2	60-mm Mortar	0.182	0.058	0.008	2.5	--	90
3-70	4309858.666	641651.432	0.25	81-mm Mortar	0.276	0.08	0.008	6.4	0	0
3-72	4309843.426	641632.303	0.25	60-mm Mortar	0.182	0.058	0.008	2.5	45	30
3-74	4309848.102	641650.780	0.3	60-mm Mortar	0.182	0.058	0.008	2.7	225	45
3-76	4309843.472	641664.147	0.2	81-mm Mortar	0.276	0.08	0.008	6.4	--	-90
3-78	4309830.166	641650.755	0.35	60-mm Mortar	0.182	0.058	0.008	2.5	330	40
3-80	4309817.969	641633.484	0.25	81-mm Mortar	0.276	0.08	0.008	6.4	180	0
3-82	4309814.256	641657.245	0.2	60-mm Mortar	0.182	0.058	0.008	2.7	270	15
3-84	4309805.611	641679.788	0.25	81-mm Mortar	0.276	0.08	0.008	6.4	0	0
3-86	4309885.192	641665.607	0.01	20-mm Projectile	0.074	0.018	0.018	100g	--	90
3-88	4309854.961	641639.131	0.01	20-mm Projectile	0.074	0.018	0.018	100g	0	0
3-90	4309846.260	641635.938	0.15	20-mm Projectile	0.074	0.018	0.018	100g	90	0
3-92	4309835.209	641642.572	0.15	20-mm Projectile	0.074	0.018	0.018	100g	120	30
3-94	4309841.825	641651.824	0.35	57-mm Projectile	0.118	0.054	0.004	0.8	330	0
3-96	4309808.212	641616.158	0.25	57-mm Projectile	0.118	0.054	0.004	0.8	30	20
3-98	4309873.375	641597.294	0.5	105-mm Projectile	0.374	0.106	0.004	13	0	-45
3-100	4309869.507	641658.196	0.91	152-mm Projectile	0.478	0.152	0.152	42.7	90	35
3-102	4309828.646	641617.038	1.2	155-mm Projectile	0.602	0.015	0.008	45.05	30	20
3-104	4309849.677	641644.479	0.76	76-mm Projectile	0.488	0.076	0.076	3.486	0	0
3-106	4309853.860	641597.683	0.5	2.75 in. Rocket	0.406	0.072	0.008	9.3	120	30

Note: To convert inches to meters, multiply by 0.0254.

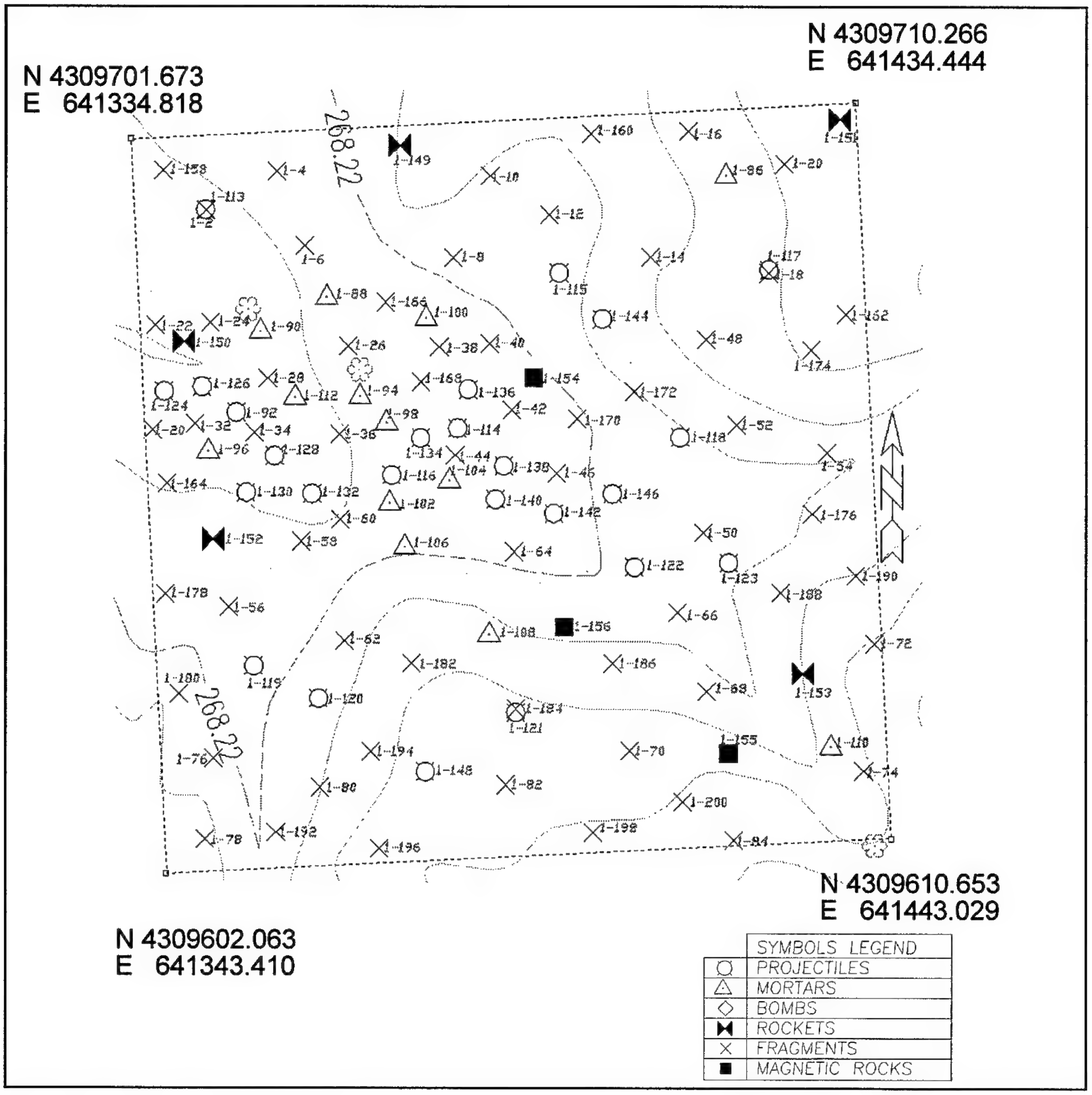

Figure 1. Area 1 item locations

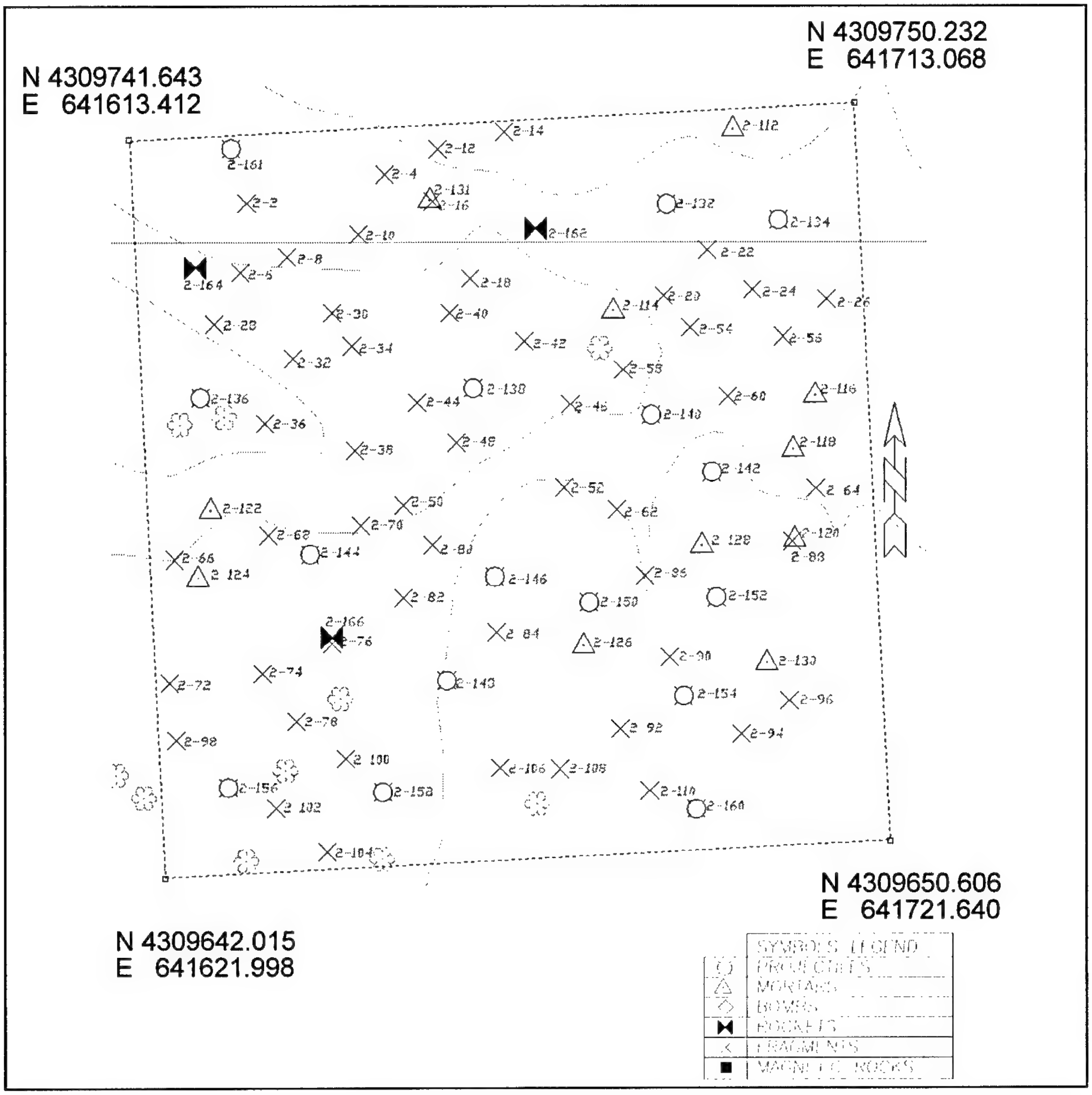

Figure 2. Area 2 item locations

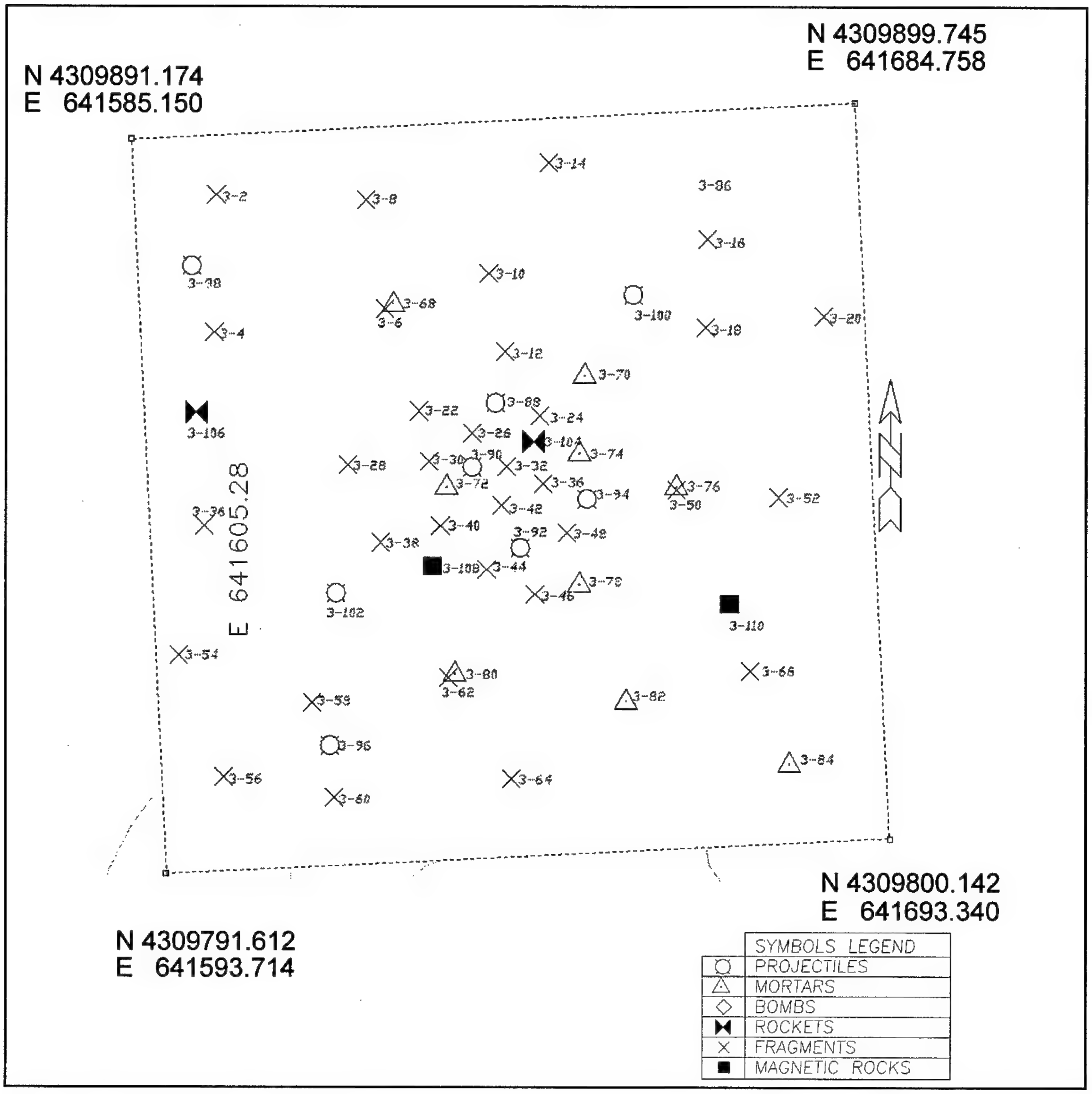

Figure 3. Area 3 item locations

2 Analysis Procedure

The target classification procedure performed on the JPG data by AETC for Geophex is based on estimating dipole model parameters from a number of GEM-3 measurements around a suspected target location (Cespedes 2001). While this classification procedure had worked well during previous demonstrations (Miller et al. 2001), it did not work very well at JPG. The target classification results achieved by Geophex for each ordnance type included in the JPG demonstration are shown in Table 4. Geophex correctly classified 39.39 percent (13/33) of the mortars, 20.75 percent (11/53) of the projectiles, and 0 percent (0/7) of the rockets for a total of 25.8 percent (24/93) of the UXO items in the area. The results for projectiles were actually worse than it appears, because only 2 out of 33 of the larger projectiles were properly classified. The other nine properly classified projectiles were 20-mm projectiles, the classification of which generated a large number of false alarms as well. Over one-half (48/93) of the targets were classified as non-ordnance clutter. The Geophex Classification results aggregated by ordnance size are shown in Table 5. The GEM-3 data from the JPG demonstration were analyzed by ERDC personnel to determine whether classification results better than those achieved by Geophex were possible and to identify possible problems or limitations of the GEM-3.

Approach

The approach taken in the U.S. Army Engineer Research and Develoment Center (ERDC), Vicksburg, MS, analysis of the performance of the GEM-3 at JPG was to extract data points collected near each of the actual target locations and compare them to the calibration data acquired with known targets at the beginning of the demonstration. Throughout this report, the term "data point" refers to a GEM-3 measurement consisting of both the in-phase and quadrature measurements for each of the seven frequencies for which data were collected during the JPG demonstration. The seven frequencies used were 90; 150; 330; 930; 2,790; 8,190; and 20,010 Hz. A computer program was developed to extract the data points and analyze the background signature for the set of data points near each target. A second computer program was developed to compare the extracted data points with calibration signatures. This was done to determine how well the data collected near each actual target matched the calibration signatures for the same ordnance type and the extent to which the data could be differentiated from other ordnance types. In addition, data points near all the objects declared by Geophex were compared with the calibration signatures to

Table 4 Geophex Classification Matrix for Areas 1, 2, and 3												
					Ordnance Type							
Geophex Classification	20 - mm	57 - mm	76 - mm	105 -mm	5- in.	152 - mm	155 -mm	60 - mm	81 - mm	4.2- in.	2.75- in.	False Alarms
Projectile 20-mm	9	0	1	0	0	0	0	0	0	0	0	152
Projectile 57-mm	0	1	0	0	0	0	0	1	0	0	0	6
Projectile 76-mm	0	0	0	0	0	1	0	2	0	0	4	15
Projectile 105-mm	0	0	0	0	0	0	0	0	1	0	0	1
Projectile 5-in.	0	0	0	0	0	0	0	0	0	0	0	4
Projectile 152-mm	0	0	0	0	1	1	1	0	0	0	0	4
Projectile 155-mm	0	0	0	0	0	0	0	0	0	0	0	1
Mortar 60-mm	0	2	0	1	0	0	0	4	0	0	0	56
Mortar 81-mm	0	0	0	1	0	1	0	0	7	0	0	10
Mortar 4.2-in.	0	0	0	0	2	0	0	0	0	2	0	1
Rocket 2.75-in.	0	0	1	0	0	0	0	0	1	0	0	5
Nonordnance Low/Med	10	6	2	0	1	1	1	6	1	0	3	181
Nonordnance High	1	1	1	2	0	1	3	2	5	1	0	65
												0
Total	20	10	5	4	4	5	5	15	15	3	7	501
% classified	45.0	10.0	0.0	0.0	0.0	20.0	0.0	26.7	46.7	66.7	0.0	
Note: To convert inches to meters, multiply by 0.0254.												

Table 5 Geophex Classification Matrix for Areas 1, 2, and 3 Aggregated by Ordnance Size				
Geophex Classification	Ordnance Type			
	20-mm	57-81-mm	105-155-mm	False Alarm
20-mm	9	1	0	152
57-81-mm	0	23	4	92
105-155-mm	0	1	7	11
Nonordnance	11	27	10	246
Total	20	52	21	501
% classified	45.0	44.2	33.3	49.1

determine the degree of confusion caused by nonordnance clutter. In addition to analysis of the JPG data, new measurements were made with the GEM-3 for several minutes over a target area to determine the statistical variability of the instrument.

Extraction of Data Points

Because of the size of these data sets (in excess of 20 megabytes each) that were acquired for each demonstration area at JPG, it was necessary to develop a way to extract the relevant data for analysis. A graphical user interface program, GridScan, was written to allow the user to extract the data near a given by Global

Positioning System (GPS) coordinate for analysis. GridScan reads in a list of targets and their location and extracts these data within a user-defined box about the item for analysis. The list of points consists of either the GPS locations given by Geophex or in the ground truth. In addition, GridScan generates histograms of a user-defined square annulus around the target and outputs these data for use in background determination. A screen shot of GridScan can be seen in Figure 4. This program was written first in an effort to determine if there was anything wrong with the locations chosen for analysis or the data itself.

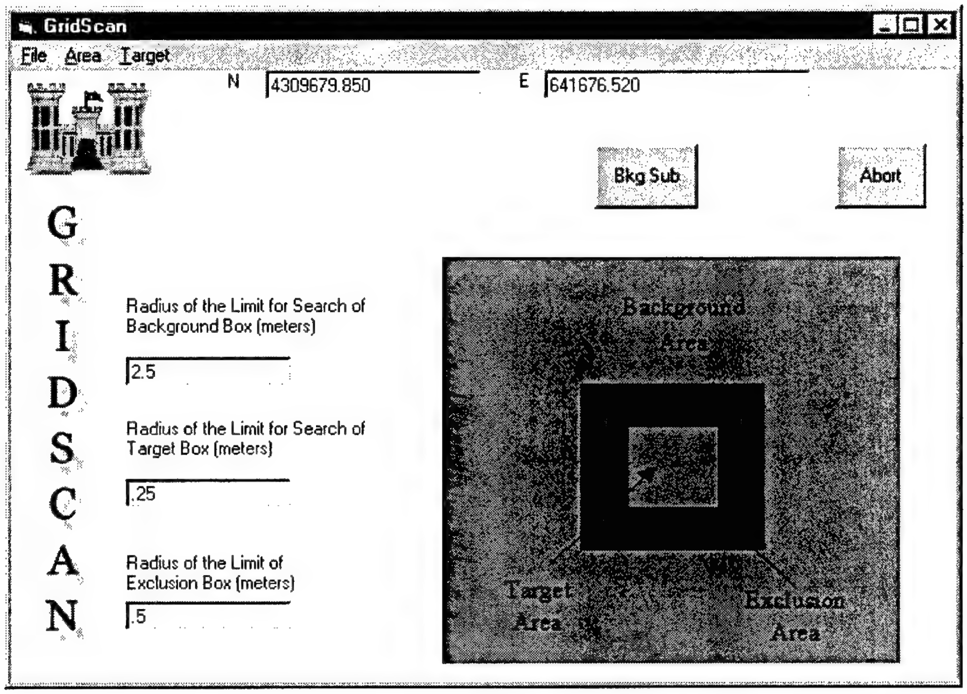

Figure 4. GridScan control screen

The procedure used by ERDC personnel to analyze the JPG GEM-3 data began with first selecting one of the three test plot areas to be searched by checking the appropriate choice in the pull down menu (Figure 5). This selects the correct file that contains all of the raw data from that area. Next the user would select to search for either target items, fragments (clutter items), or for both target and fragment items (Figure 6). The choice of options will determine which file containing item locations is to be used. If "targets" is selected, then the file containing the target GPS locations is used and searches these data one at a time. The last option was to allow for the use of the Geophex chosen locations file to be used.

The user then determined the area of the search by selecting the area around the point to include in the search area, the area to exclude around that point, and then the area to be included as background. The exclusion area was used to remove the influence of any large target from the background to better determine the actual background signal in the area of the target. This selection of the background area size must be done carefully. If the area chosen is too large, it may include other targets or clutter items.

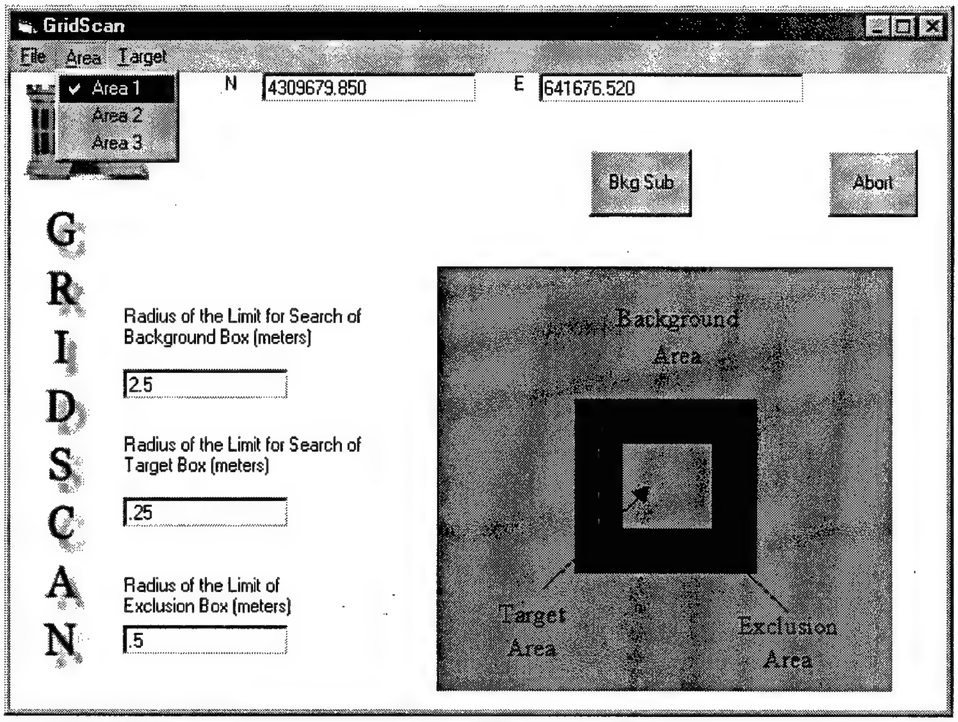

Figure 5. GridScan control screen showing the area selection pulldown menu

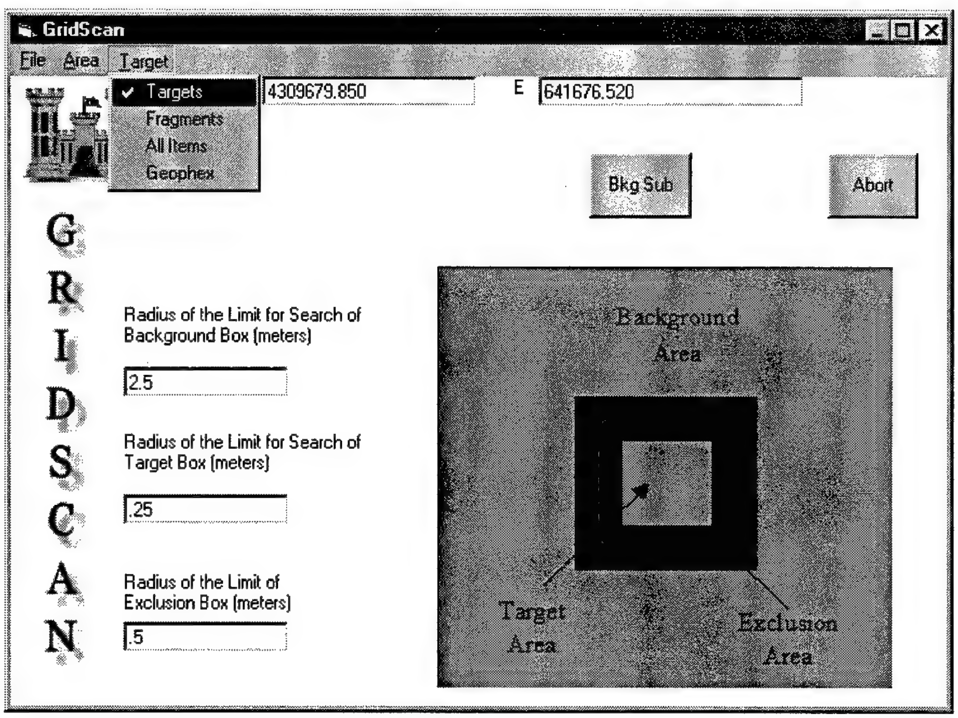

Figure 6. GridScan control screen showing the target/item selection pulldown menu

Once all of the parameters have been decided, the user runs the program by selecting File > Process Data (Figure 7). Now the data will be searched for the points of interest. When this is finished running, the user will implement the Background Subtract. This will use an average of the local background around the item as the background to be subtracted for each item. All of this information is saved in an ASCII file that has the item number, GPS location, and all the measured data associated with that point for more indepth analysis.

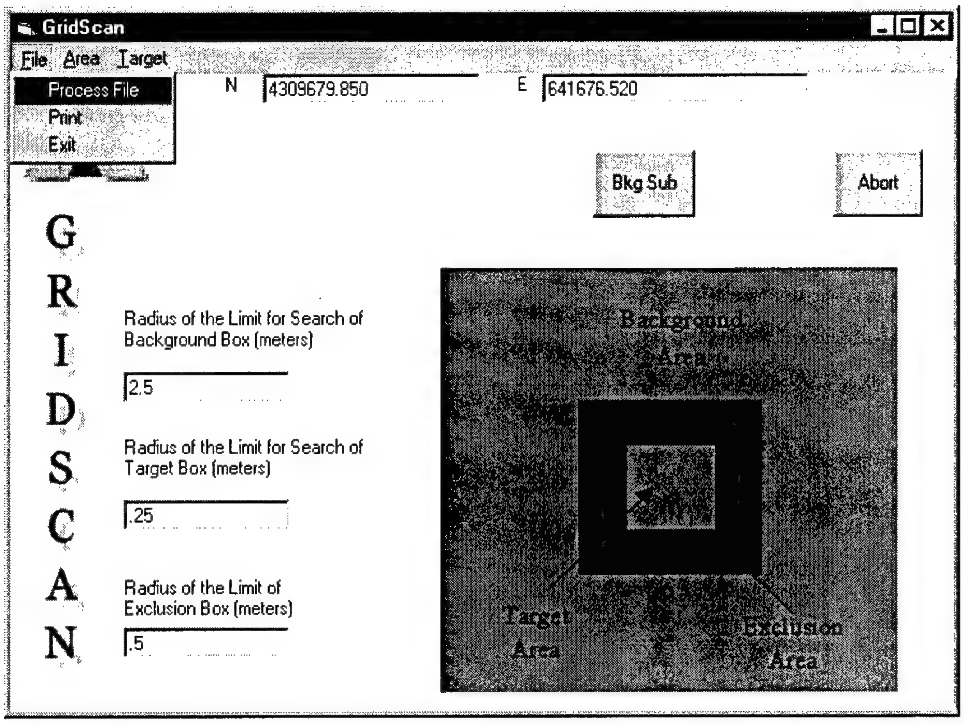

Figure 7. GridScan control screen showing the file action pulldown menu

An additional feature was implemented into GridScan for help in background calculation. The routine creates a histogram of the data that were selected for use as the background. If these data create a single well-defined peak, this indicates that the background is fairly homogenous and isotropic. Dual peaks or skewed distributions indicate that a different method of determining the background should be used. This could be caused by a detector shift and should be handled by treating the shifted areas separately. The background will be the most prominent feature and should have distributions around the average background signal strength. Also, smaller peaks will be seen. These peaks will represent the various items buried in the area.

Background variability in the data set adds uncertainty or error to the target signature and this degrades the viability of classification algorithms. To better understand the background contribution to the uncertainty in the data set, it is necessary to characterize the background so that it could be removed from the target data set. For the purpose of this investigation, the target data were defined as the points within a 1-m box centered on each target, and these data were extracted for classification analysis. The background data were defined as the

data within a 5-m box about the target excluding the 1-m target data set. To determine the best background value to subtract from the target, a histogram of the values in the background was created. Then, the centroid of the largest peak in that set was chosen as the background value.

From Figure 8, it is apparent that the majority of the measured values around item 3-74 at frequency 2,790 Hz have a value of approximately 2.5. This well-defined peak is what would be expected from a measurement over a fairly homogeneous medium. In this case, the centroid is a good measure of the background value.

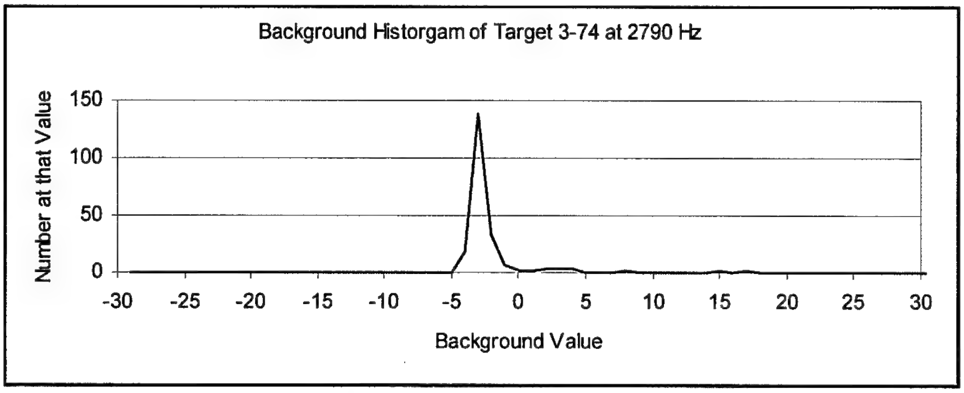

Figure 8. Histogram representation of background for target 3-74 at 2,790 Hz

Figure 9 shows an upward shift, but it also displays a double peak. Simply picking the largest peak will not work for this case. It is obvious from the multiple peak structure here that the background is not homogeneous over the region that was extracted. For the purpose of this analysis, background was chosen as the center of mass of this distribution. When analyzing targets with this sort of background, the analyst can consider the error introduced by the background to determine if the measurement has sufficient accuracy to make a classification.

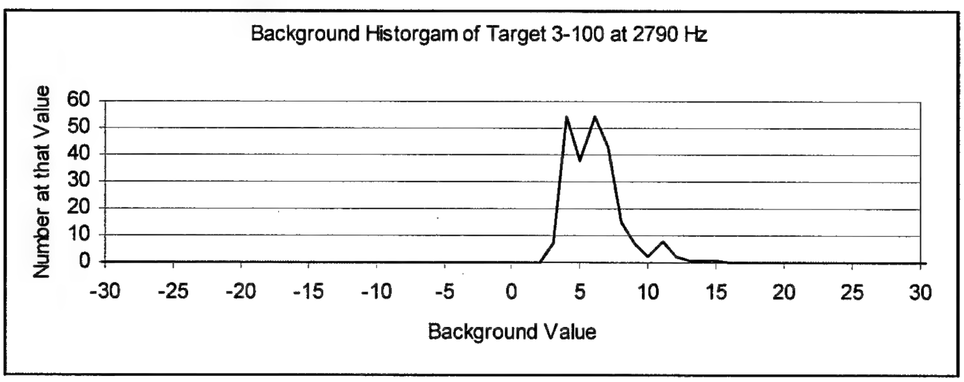

Figure 9. Histogram representation of background for target 3-100 at 2,790 Hz

Figures 10 through 16 show a typical set of in-phase measurements and are presented so the variation in the distribution as a function of frequency can be seen.

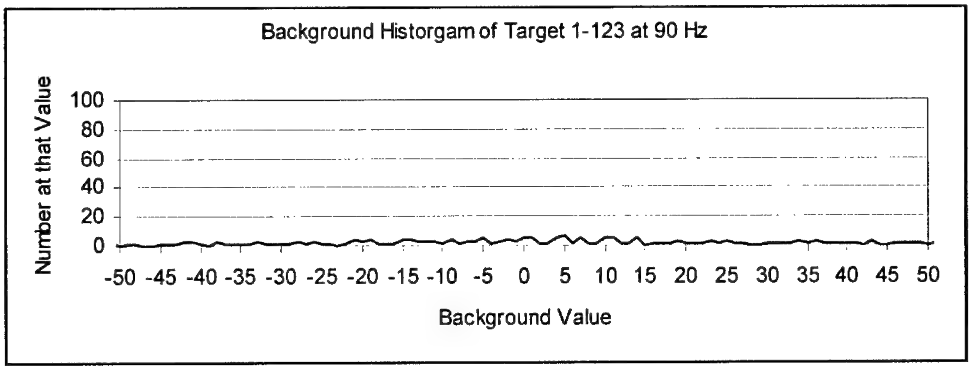

Figure 10. Histogram of background for target 1-123 at frequency 90 Hz

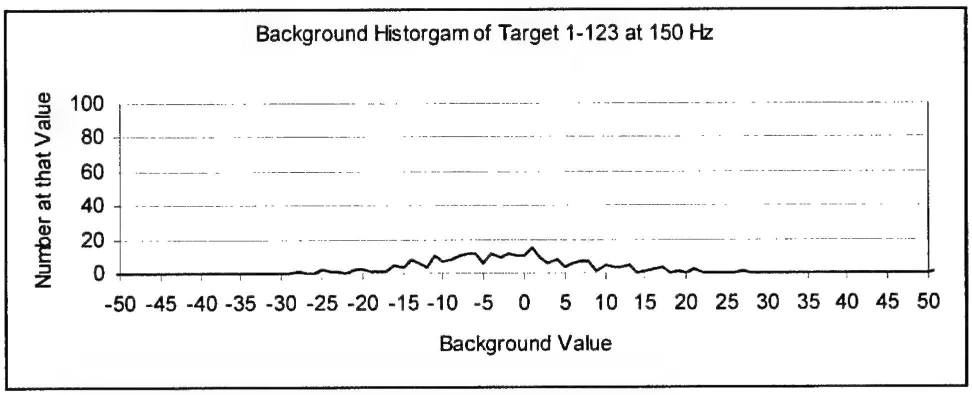

Figure 11. Histogram of background for target 1-123 at frequency 150 Hz

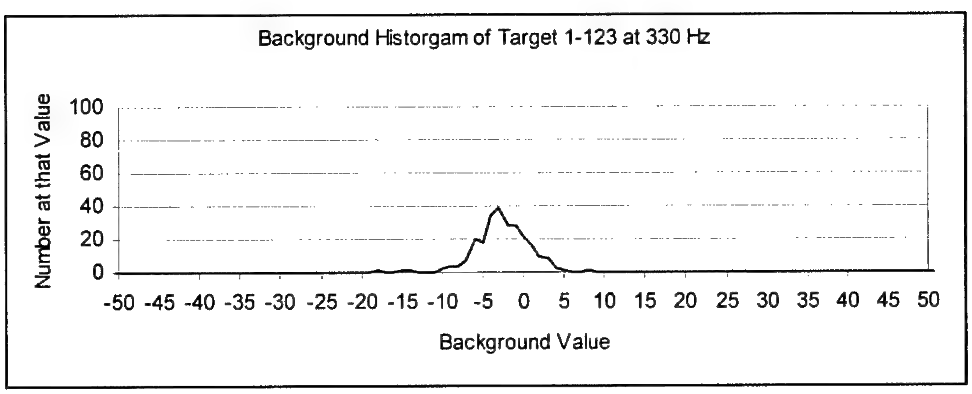

Figure 12. Histogram of background for target 1-123 at frequency 330 Hz

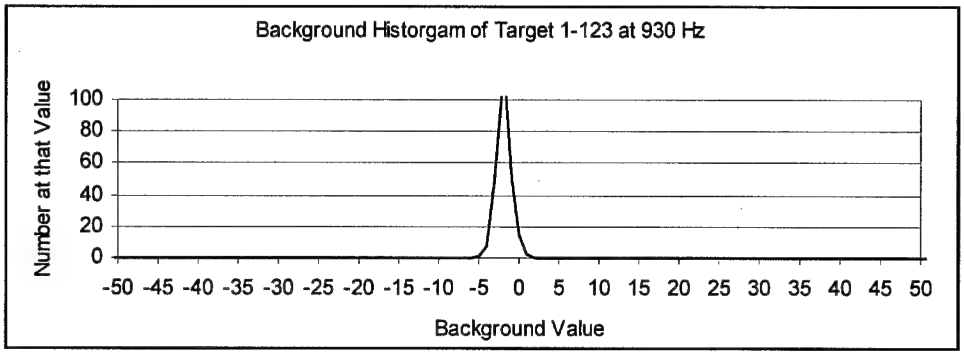

Figure 13. Histogram of background for target 1-123 at frequency 930 Hz

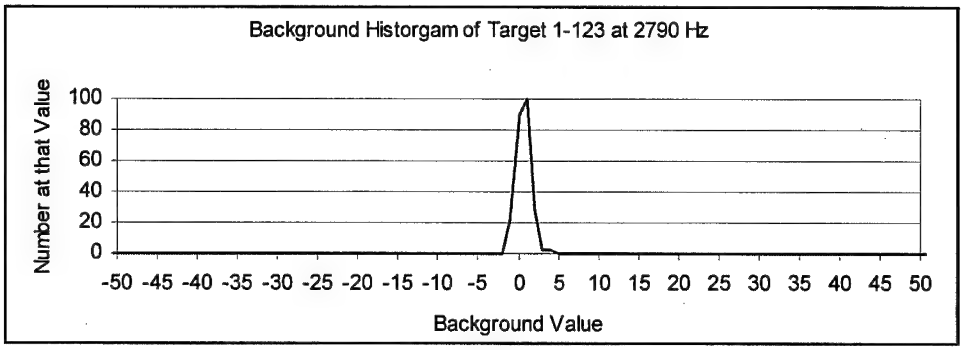

Figure 14. Histogram of background for target 1-123 at frequency 2,790 Hz

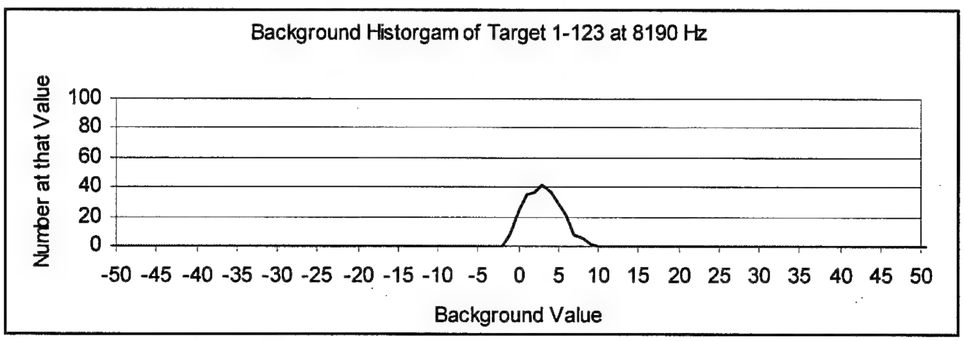

Figure 15. Histogram of background for target 1-123 at frequency 8,190 Hz

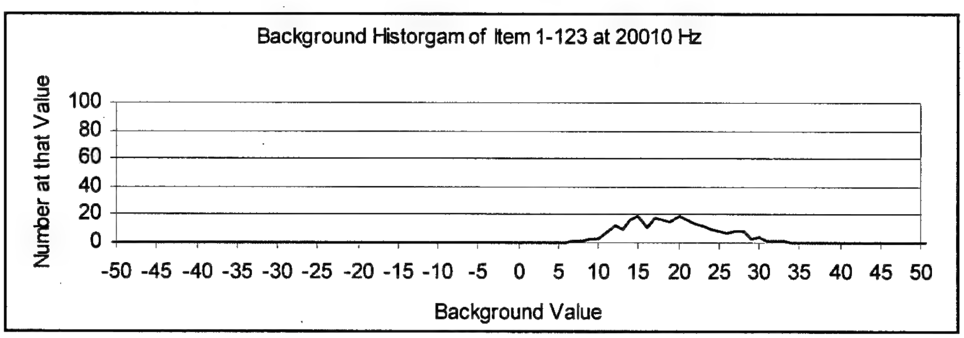

Figure 16. Histogram of background for target 1-123 at frequency 20,010 Hz

Typically, the lower frequencies produce a broader distribution in the measurements narrowing at frequencies 930 and 2,790 Hz while broadening back out for 8,190 and 20,010 Hz. With most scientific instruments, it is common to discuss the accuracy of the instrument. In this case, that is not a straightforward thing; the uncertainty in the measurement is a function of the background homogeneity as well as frequency.

Analysis of Data Points

Calibration data

While at the site, calibration data were acquired by passing the GEM-3 over each type of ordnance placed in an open trench, as shown in Figure 17. Because of sensor problems at the site, the available calibration data were very limited. No calibration data were available for the 76-mm, 105-mm, and 127 mm (5-in.) projectiles. For the other ordnance types, data were collected with inclination angles of 0, 90 (nose up), and -90 (nose down) deg. Because the actual targets were buried with many different inclination angles and the inclination angle has a significant influence on the signature of the target, data were interpolated between these three measurements at 5-deg increments. Data were collected at multiple depths for some ordnance types but not for others. Because depth appears to affect only the magnitude of the data and not the shape of the curves, the data at the shallowest depth for each ordnance type were selected for analysis to simplify the process. The calibration data at 0, 90, and -90 deg are shown for each of the available ordnance types in Figures 18 through 25.

Figure 17. Acquisition of calibration data with the GEM-3

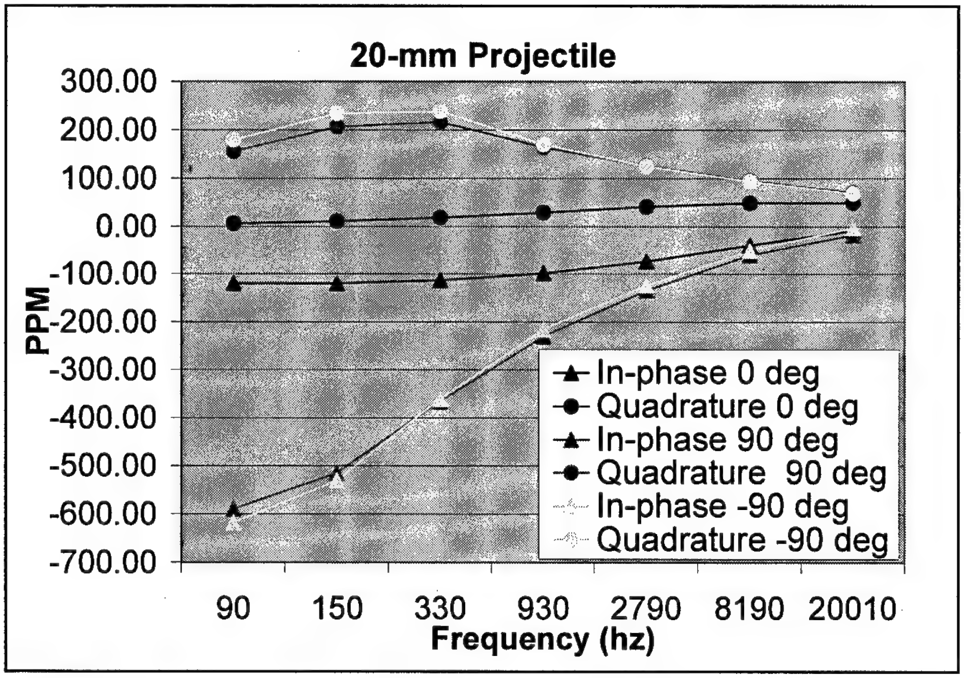

Figure 18. Calibration data for 20-mm projectile

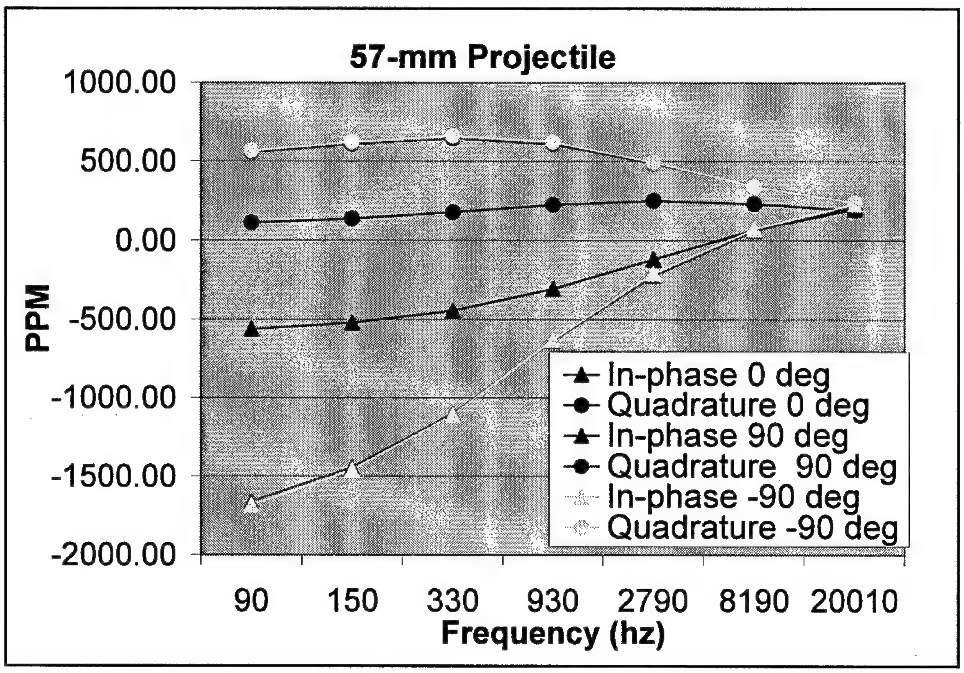

Figure 19. Calibration data for 57-mm projectile

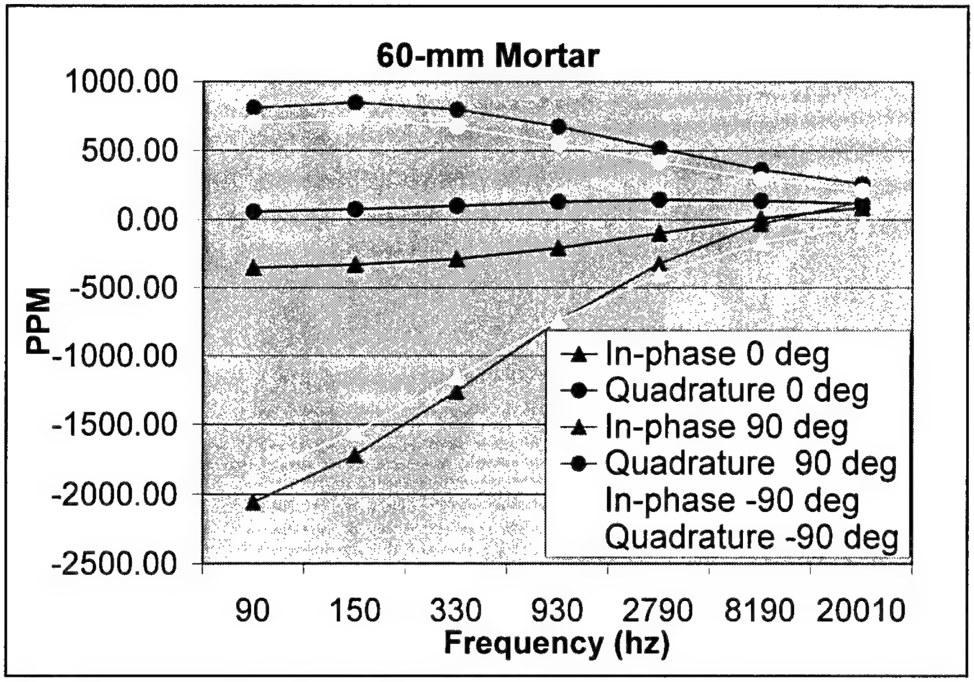

Figure 20. Calibration data for 60-mm mortar

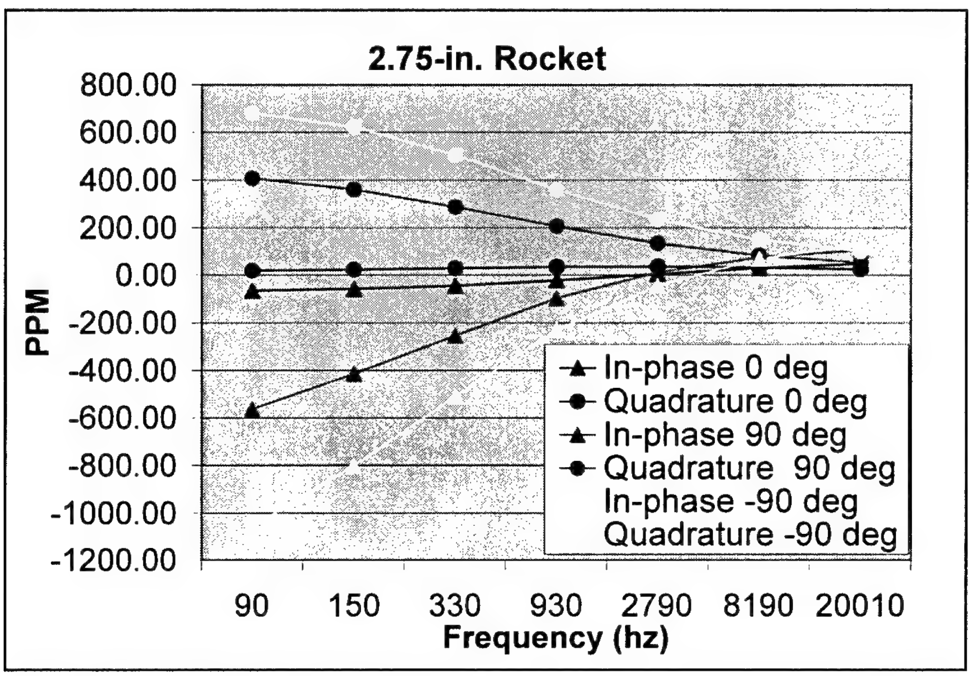

Figure 21. Calibration data for 2.75-in. rocket (To convert inches to millimeters, multiply by 25.4)

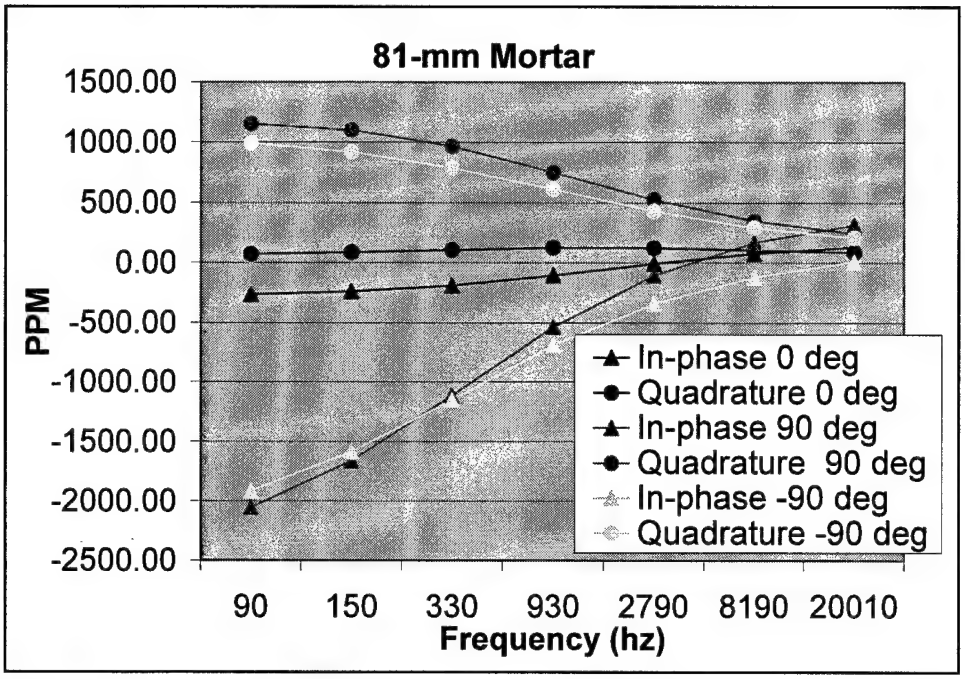

Figure 22. Calibration data for 81-mm mortar

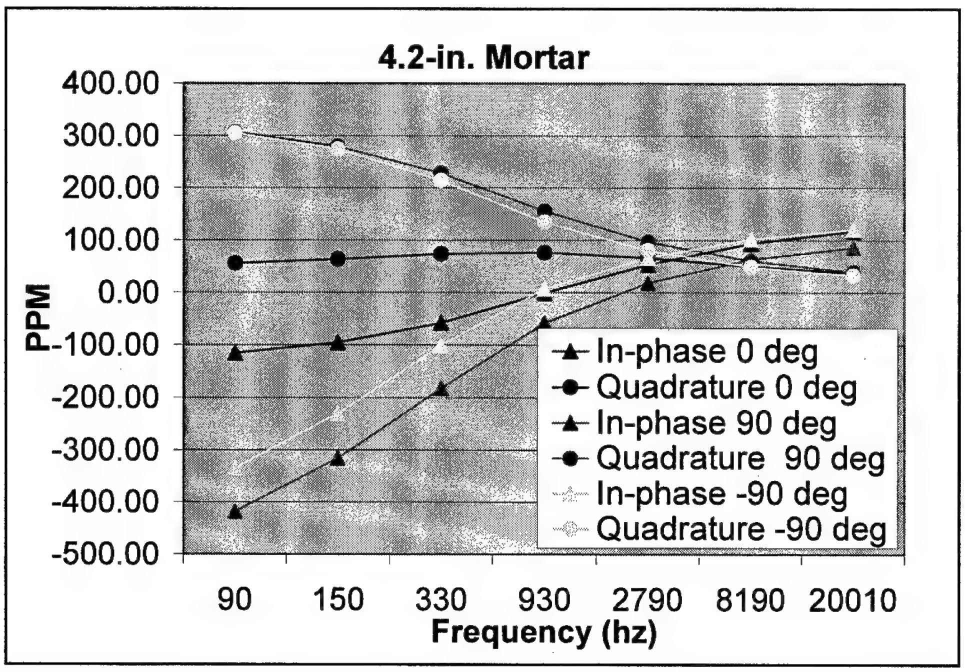

Figure 23. Calibration data for 4.2-in. mortar (To convert inches to millimeters, multiply by 25.4)

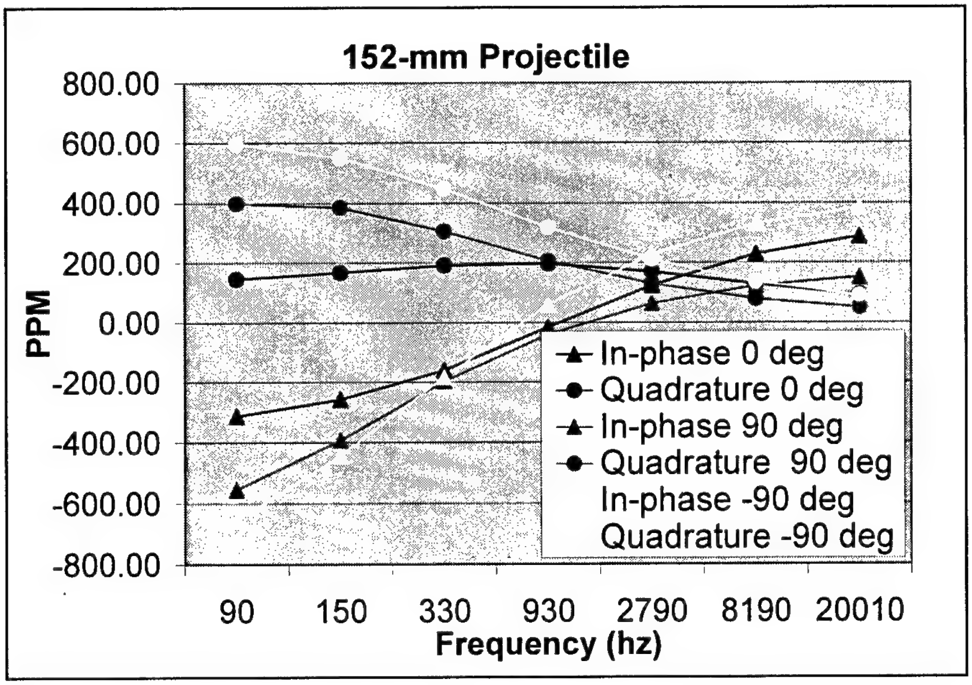

Figure 24. Calibration data for 152-mm projectile

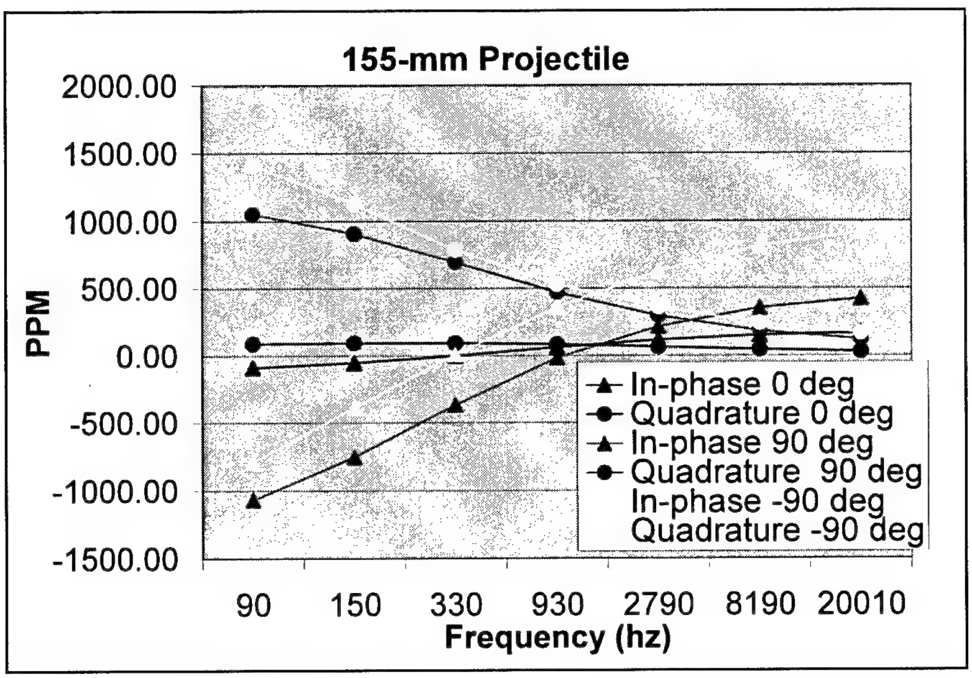

Figure 25. Calibration data for 155-mm projectile

Error in fit

A simple measure of the error in fit between a data point and a calibration signature was used. The error in fit was calculated separately for the in-phase and quadrature and then summed to get a single measure. When comparing a data point to a calibration signature, the frequency measurements for the data point were normalized to make the total in-phase and quadrature responses for the data point equal to the total in-phase and quadrature responses, respectively, of the calibration signature. Once the magnitudes were equalized, the error in fit, E, was calculated by

$$E = \frac{\sqrt{\sum_{k=1}^{k=7}(CI_k - PI_k)^2}}{\sum_{k=1}^{k=7}|CI_k|} + \frac{\sqrt{\sum_{k=1}^{k=7}(CQ_k - PQ_k)^2}}{\sum_{k=1}^{k=7}|CQ_k|} \tag{1}$$

where CI_k = calibration in-phase response

PI_k = data point in-phase response at frequency k

CQ_k and PQ_k = calibration and data point quadrature responses, respectively, at frequency k

Analysis program

A graphical user interface computer program was developed to automate the process of comparing data points with calibration signatures under various conditions. A view of the program's user interface is shown in Figure 26. The two text boxes at the top of the screen are used to select objects of interest. The "Actual Targets" box lists the Target IDs and ground truth information for all of the targets that were emplaced in one of the three areas at JPG. The area currently visible is selected by radio buttons at the bottom of the screen. The "Detected Objects" box lists the IDs for all objects declared as targets by Geophex in the currently selected area. If the object corresponds to an actual target, the Target ID is listed. If not, the Geophex ID for the object is shown. Selecting an ID in either of these text boxes will cause the other text boxes and graphics windows to be updated reflecting the selection. The center textbox, labeled "Best Matches to Calibration Data," consists of one line for each data point near the selected object that lists the ID, the total in phase and quadrature magnitude, the distance from the target if the object is a known target, and information about the three closest matches of the point with calibration data. The information for each match consists of the ordnance type, depth, and inclination and the error between the data point and the calibration signature. The left graphics window shows the in-phase and quadrature data for the selected data point and for the calibration data. The calibration data displayed is for either the best matching ordnance or the actual ordnance corresponding to the current Target ID, depending on the status of the "Show Best Match" check box. The right graphics box shows the

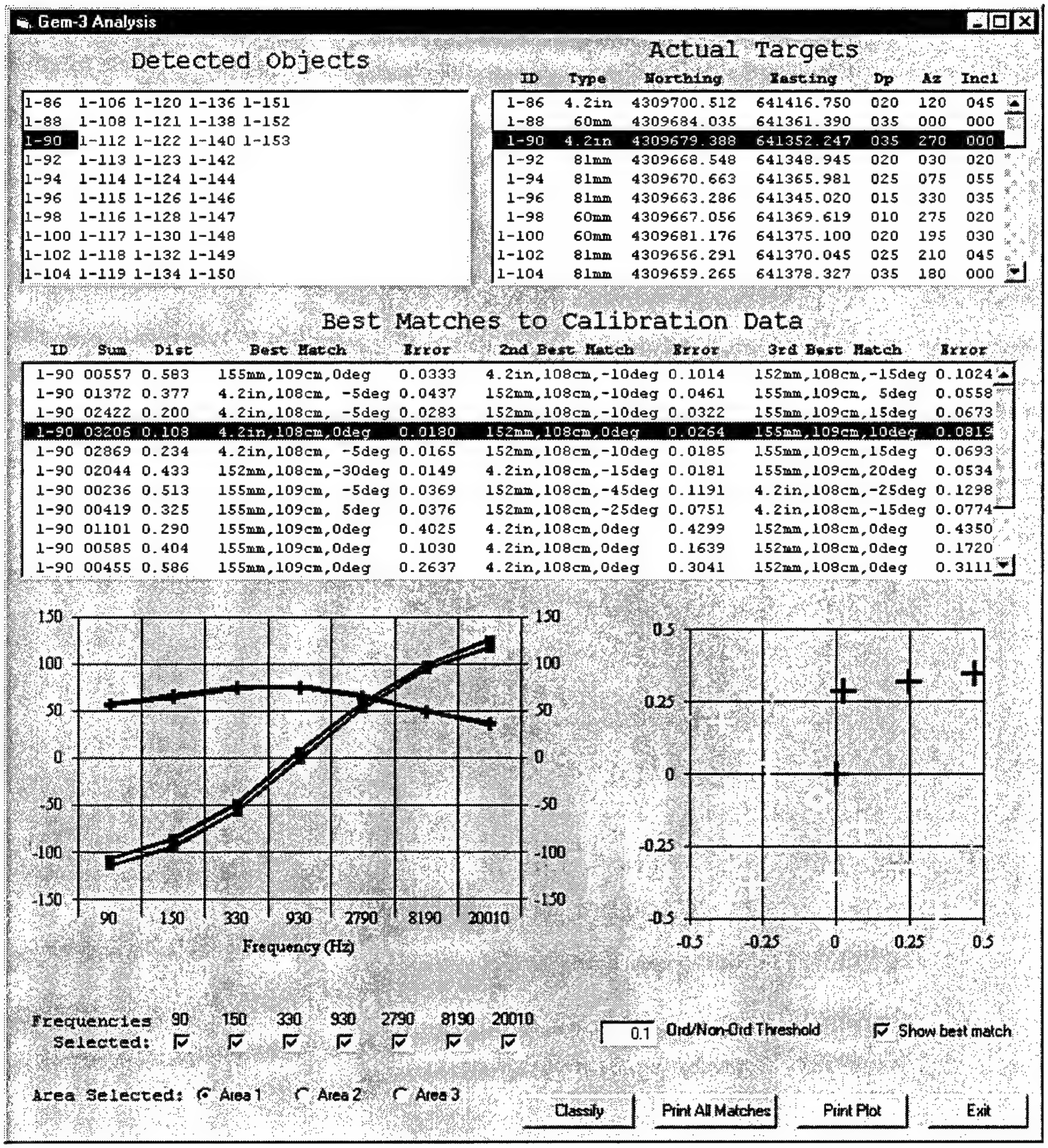

Figure 26. GEM-3 Analysis Program screen dump

positions of the data points around the actual target location shown at the origin in red. Points with match errors greater than the current ordnance/nonordnance threshold are shown in black. Points with errors less than the threshold, but greater than two-thirds of the threshold, are shown in dark blue. Points with errors between one-third and two-thirds of the threshold are shown in cyan. Points with errors below one-third of the threshold are displayed in yellow. The currently displayed data point is shown as a diamond rather than a plus. A row of check boxes at the bottom of the screen allows individual frequencies to be excluded from calculations. An operator can also select individual frequencies to be excluded from calculations through the graphical user interface.

3 Results

Area Coverage

Complete area coverage is essential for determining the performance of a UXO detection system. A rendering of the positions where measurements were made in Areas 1, 2, and 3 can be seen in Figures 27, 28, and 29, respectively. Coverage maps showing the distribution of quadrature and in-phase values for each frequency are included as Appendix A. From the graphics it can be seen that there were some failures in coverage, but fortunately these glitches did not occur over any of the target locations.

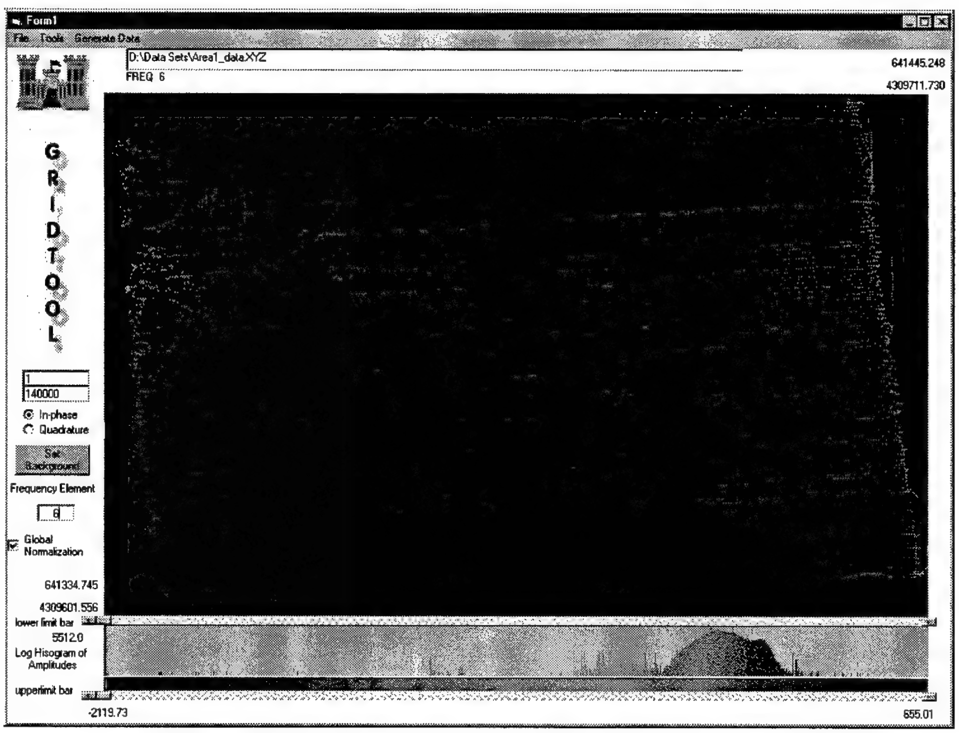

Figure 27. Area 1 measurement positions

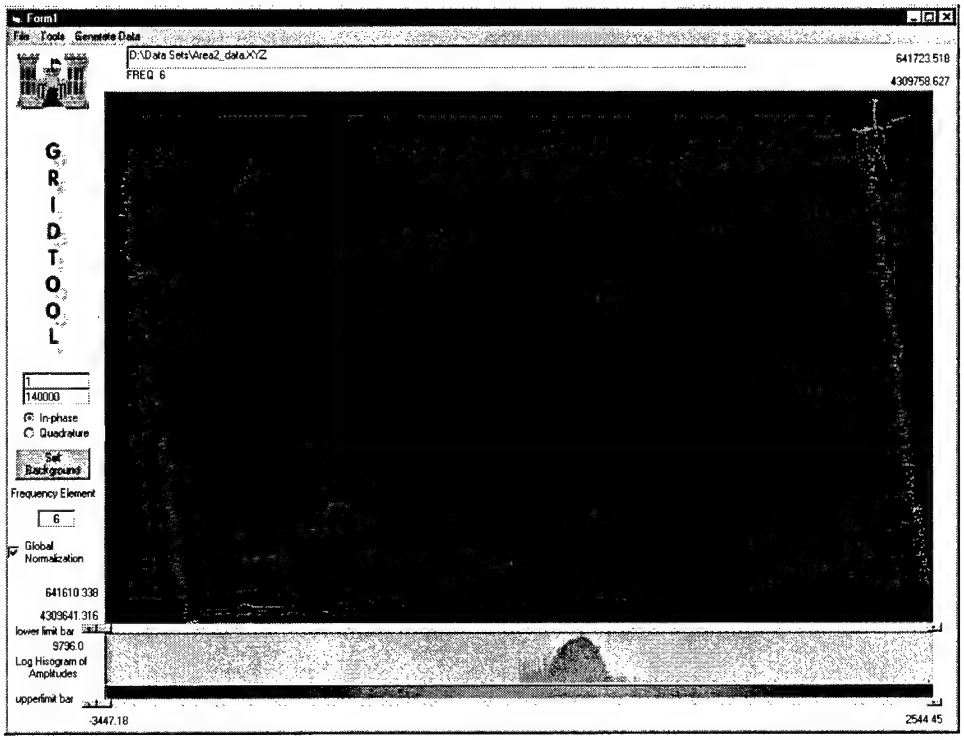

Figure 28. Area 2 measurement positions

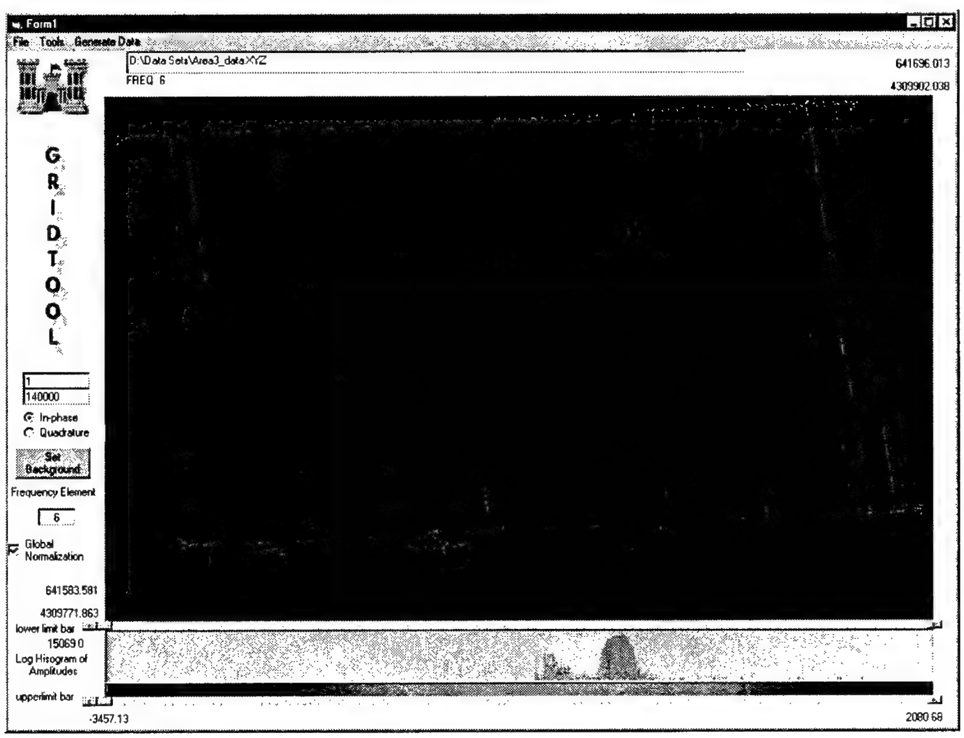

Figure 29. Area 3 measurement positions

Table 6 shows the number of data points within a 1-m box centered on each target and the distance from the target of the closest point. No target is identified for which measurements were not taken within ½ m.

Table 6
Proximity of GEM-3 Data Points to Targets at JPG

Target ID	Number of Points	Closest Point m	Target ID	Number of Points	Closest Point m	Target ID	Number of Points	Closest Point m
1-86	8	0.1845	1-138	9	0.2583	2-148	8	0.2552
1-88	12	0.1163	1-140	9	0.2118	2-150	11	0.078
1-90	15	0.1084	1-142	8	0.1012	2-152	10	0.1217
1-92	11	0.2047	1-144	8	0.0221	2-154	11	0.1662
1-94	5	0.3789	1-146	14	0.1985	2-156	10	0.094
1-96	10	0.254	1-147	6	0.1779	2-158	9	0.1112
1-98	8	0.0524	1-148	8	0.1818	2-160	9	0.1
1-100	7	0.1802	1-149	8	0.159	2-161	7	0.1206
1-102	7	0.037	1-150	40	0.0716	2-162	10	0.3109
1-104	7	0.0226	1-151	9	0.1703	2-164	4	0.0481
1-106	8	0.2547	1-152	9	0.2302	2-166	4	0.1448
1-108	8	0.1743	1-153	9	0.0804	3-68	10	0.099
1-112	9	0.2053	2-112	3	0.3122	3-70	9	0.312
1-113	8	0.1205	2-114	8	0.3113	3-72	10	0.1537
1-114	11	0.1056	2-116	8	0.2823	3-74	10	0.1845
1-115	8	0.2459	2-118	9	0.1788	3-76	4	0.2053
1-116	6	0.3548	2-120	8	0.2594	3-78	9	0.2821
1-117	18	0.1302	2-122	10	0.1062	3-80	13	0.1604
1-118	10	0.0977	2-124	8	0.063	3-82	7	0.2288
1-119	12	0.0546	2-126	7	0.2474	3-84	9	0.126
1-120	7	0.2299	2-128	8	0.2001	3-86	8	0.3152
1-121	9	0.0663	2-130	10	0.3674	3-88	5	0.0757
1-122	5	0.0944	2-131	7	0.2354	3-90	9	0.1502
1-123	10	0.1379	2-132	5	0.1081	3-92	6	0.0715
1-124	31	0.0136	2-134	8	0.0648	3-94	8	0.2611
1-126	10	0.1342	2-136	8	0.1592	3-96	8	0.2901
1-128	11	0.0224	2-138	7	0.4204	3-98	11	0.0272
1-130	8	0.0774	2-140	8	0.1918	3-100	10	0.058
1-132	9	0.305	2-142	11	0.1674	3-102	8	0.1774
1-134	10	0.0854	2-144	7	0.3494	3-104	12	0.124
1-136	5	0.144	2-146	18	0.1793	3-106	11	0.1329

Data Variability

To determine the precision of the instrument, an experiment was set up to collect a statistically significant number of measurements for a fixed source. The Gem-3 was placed in a wooden rack 10 cm above the ground, and first data were collected in remote mode using a 233 MHz Pentium II computer. The Geophex data display program was used to collect the data, but anomalies in the data were observed.

At irregular intervals, obviously corrupted data were plotted to the screen. A initial examination of the collected data showed that there were shifts in the data stream. Geophex advised that a 500 MHz class machine was required to make use of this software, so more data were collected in "survey mode" and the following is a discussion of these data.

Figures 30 through 50 show approximately 45 min of data that were collected to make histograms for three separate cases, background, a 20-mm projectile, and a 57-mm mortar. Table 7 shows the statistical results of this analysis.

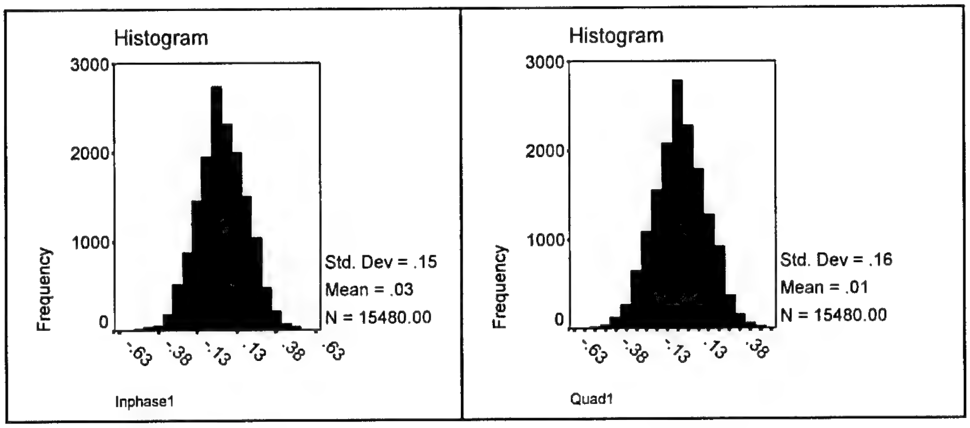

Figure 30. In-phase and quadrature histograms for background at 90 Hz

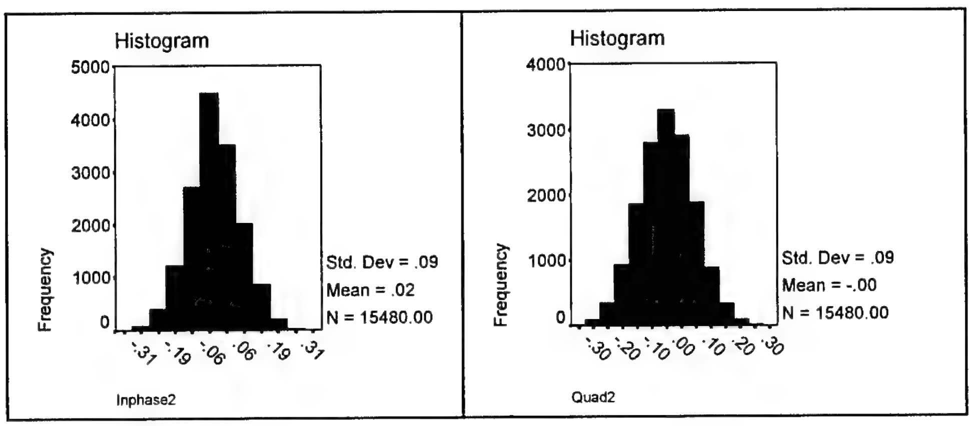

Figure 31. In-phase and quadrature histograms for background at 150 Hz

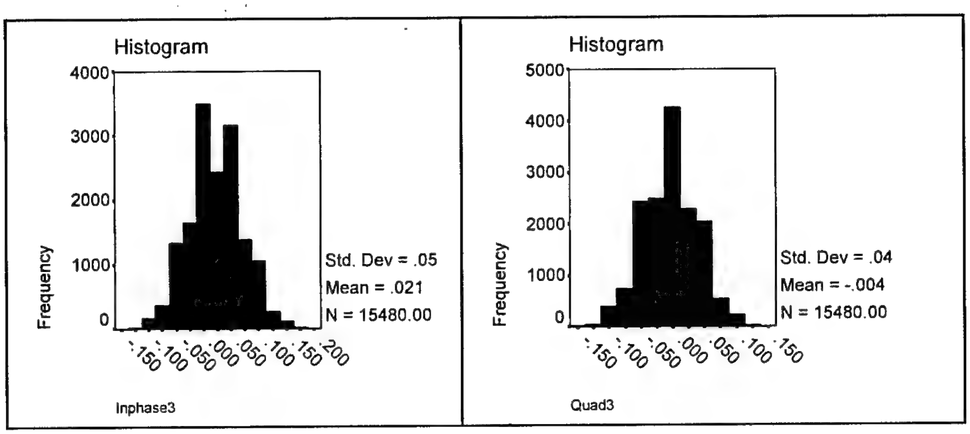

Figure 32. In-phase and quadrature histograms for background at 330 Hz

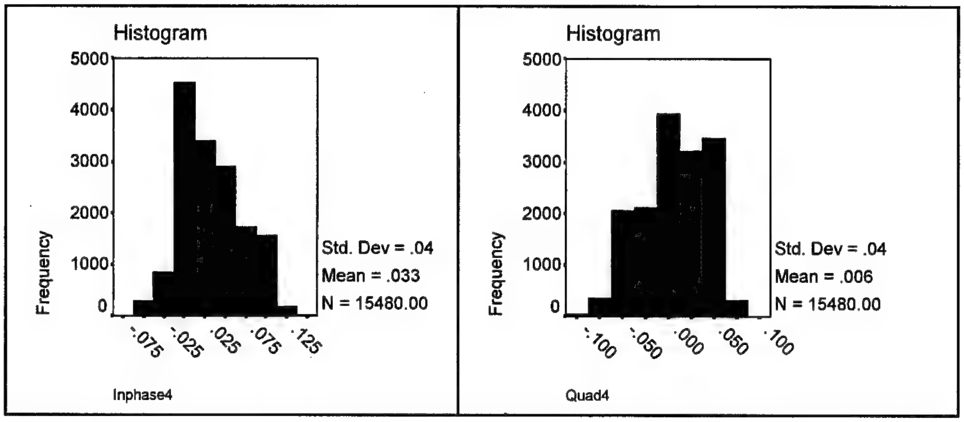

Figure 33. In-phase and quadrature histograms for background at 930 Hz

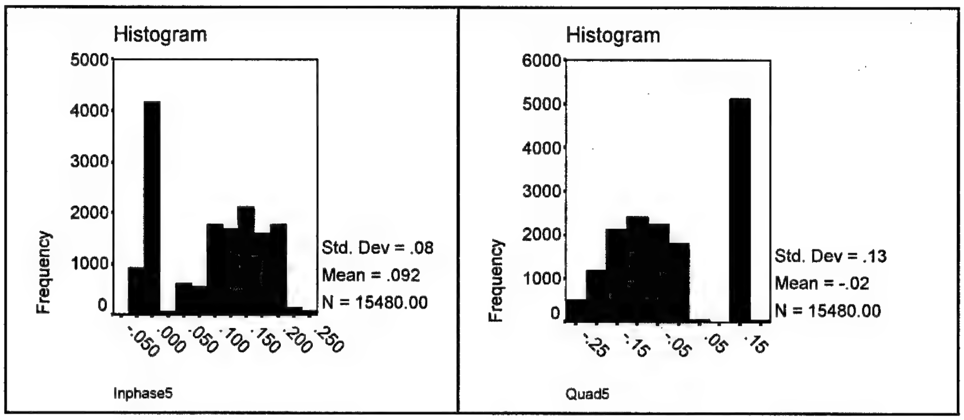

Figure 34. In-phase and quadrature histograms for background at 2,790 Hz

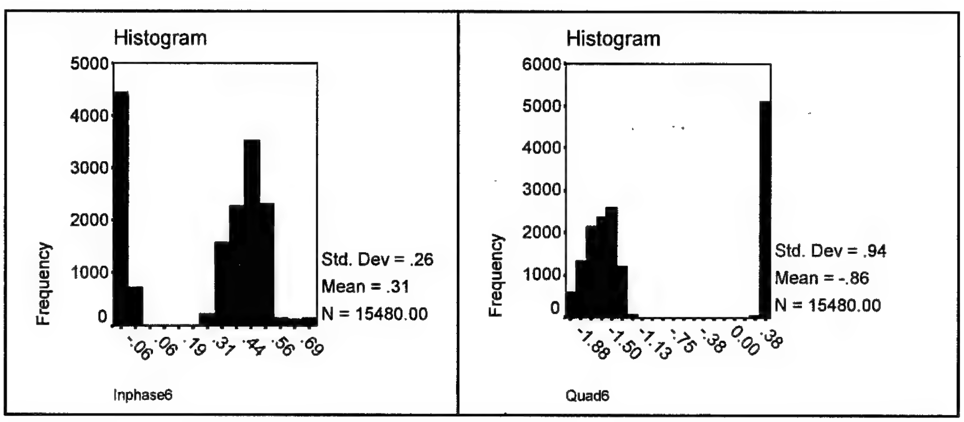

Figure 35. In-phase and quadrature histograms for background at 8,190 Hz

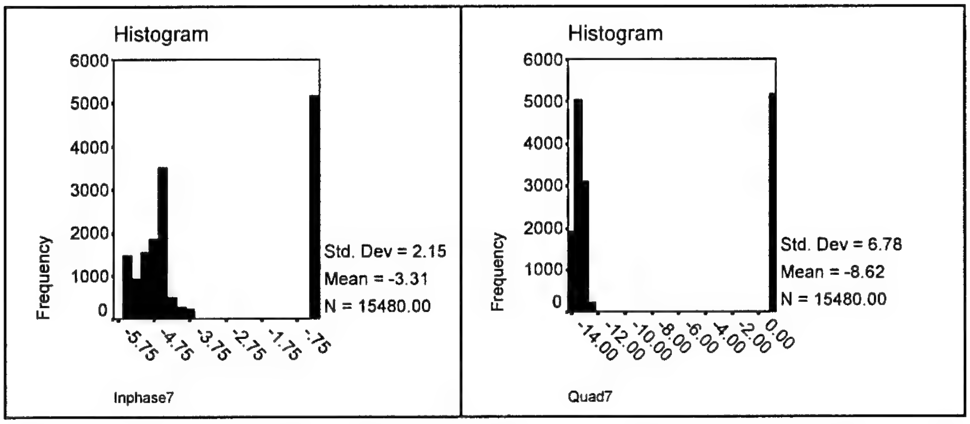

Figure 36. In-phase and quadrature histograms for background at 20,010 Hz

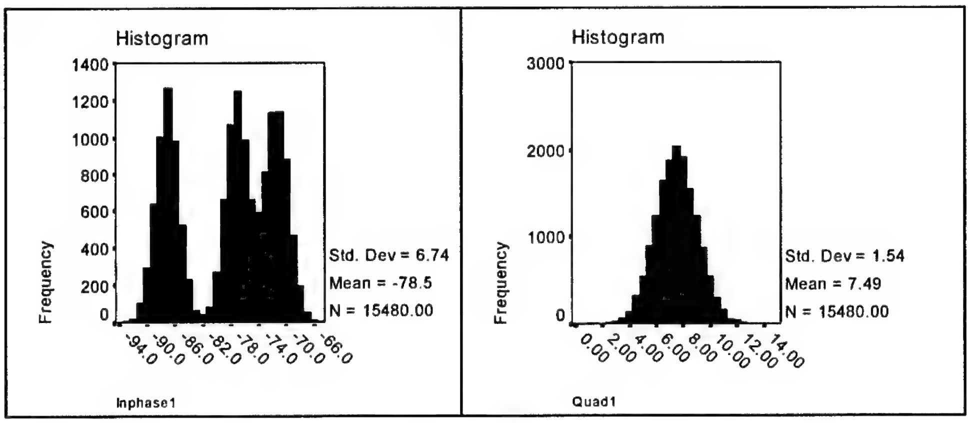

Figure 37. In-phase and quadrature histograms for 20-mm round at 90 Hz

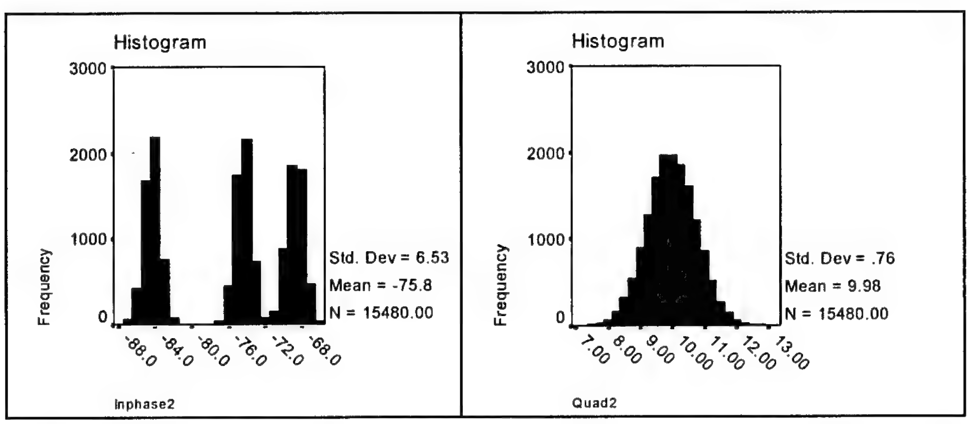

Figure 38. In-phase and quadrature histograms for 20-mm round at 150 Hz

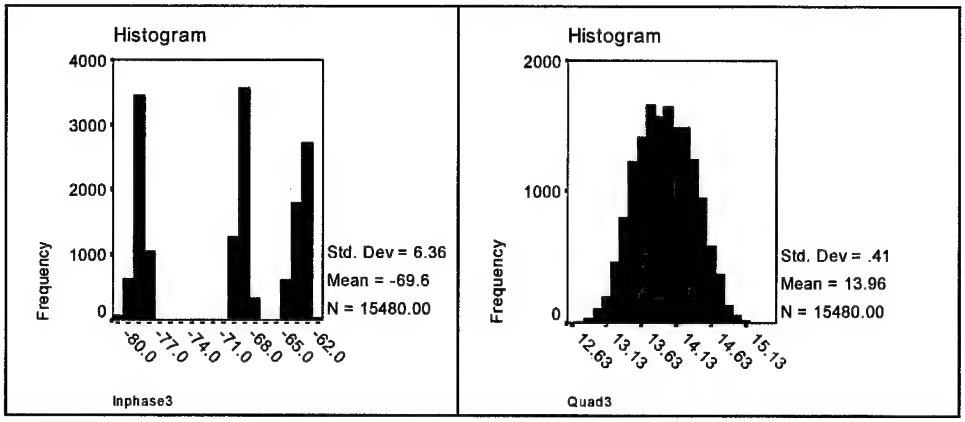

Figure 39. In-phase and quadrature histograms for 20-mm round at 330 Hz

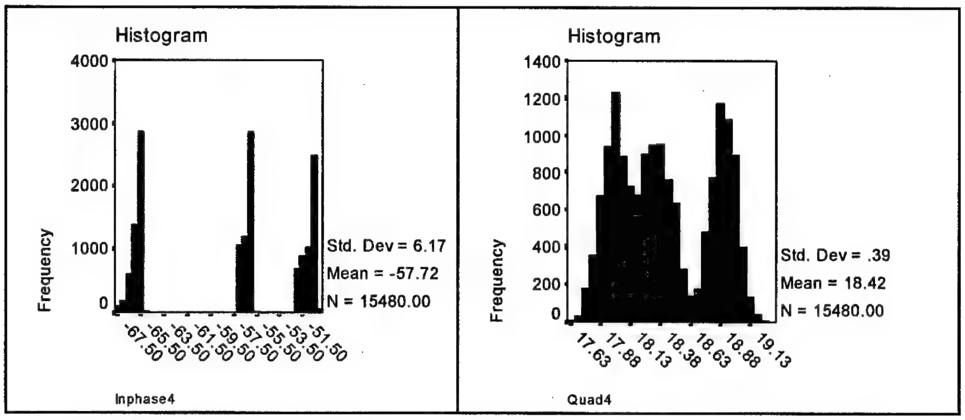

Figure 40. In-phase and quadrature histograms for 20-mm round at 930 Hz

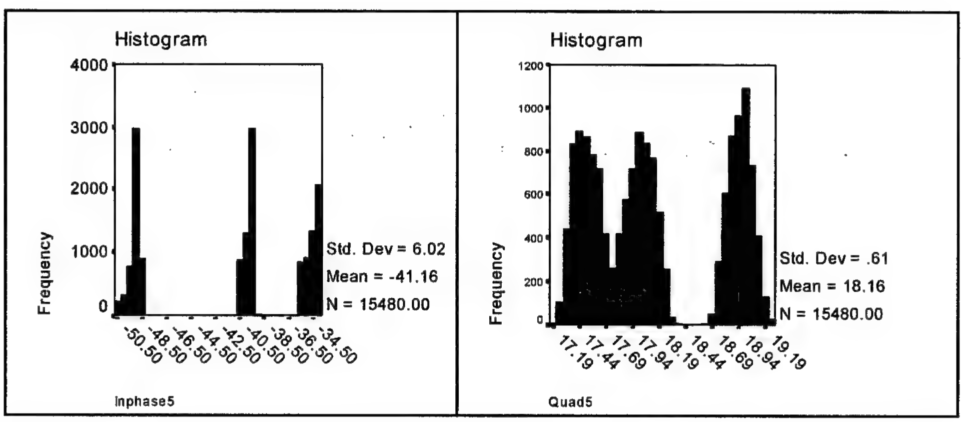

Figure 41. In-phase and quadrature histograms for 20-mm round at 2,790 Hz

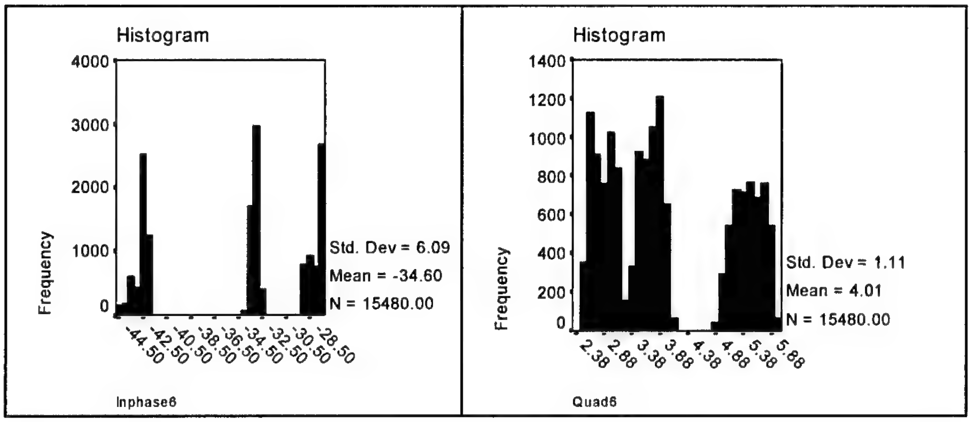

Figure 42. In-phase and quadrature histograms for 20-mm round at 8,190 Hz

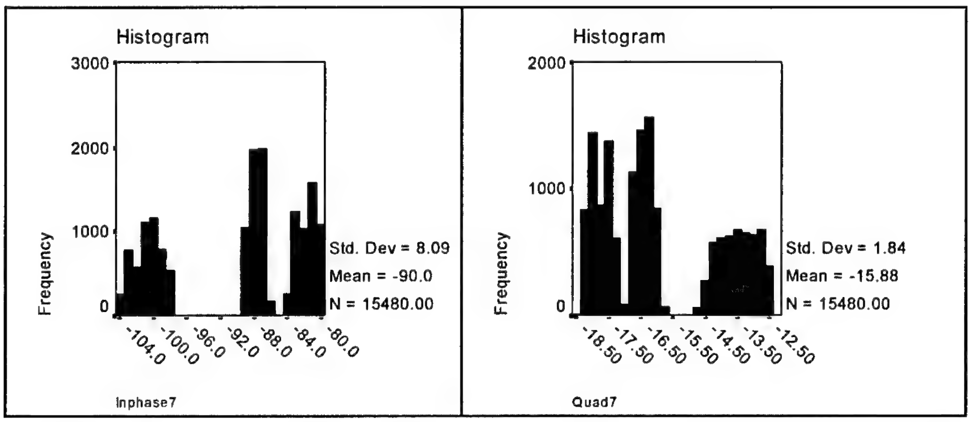

Figure 43. In-phase and quadrature histograms for 20-mm round at 20,010 Hz

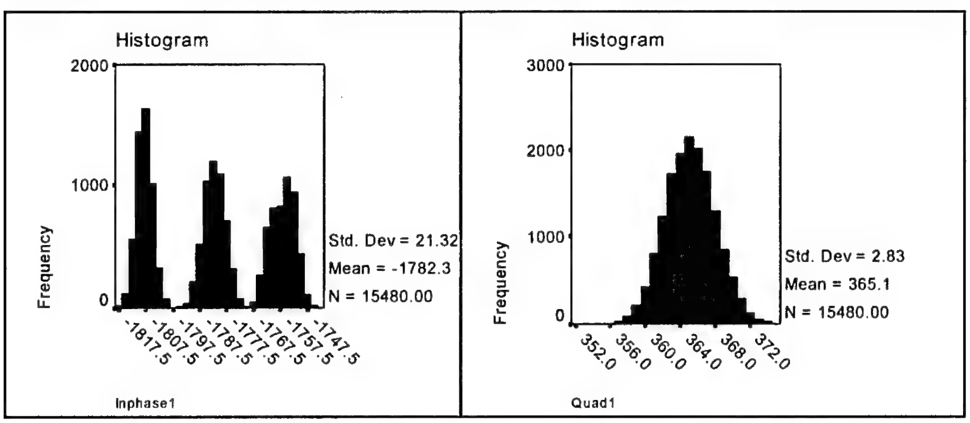

Figure 44. In-phase and quadrature histograms for 57-mm mortar at 90 Hz

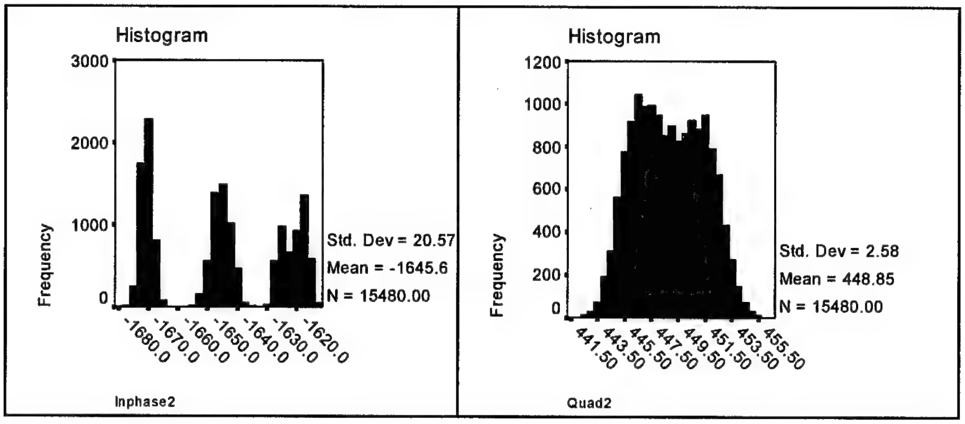

Figure 45. In-phase and quadrature histograms for 57-mm mortar at 150 Hz

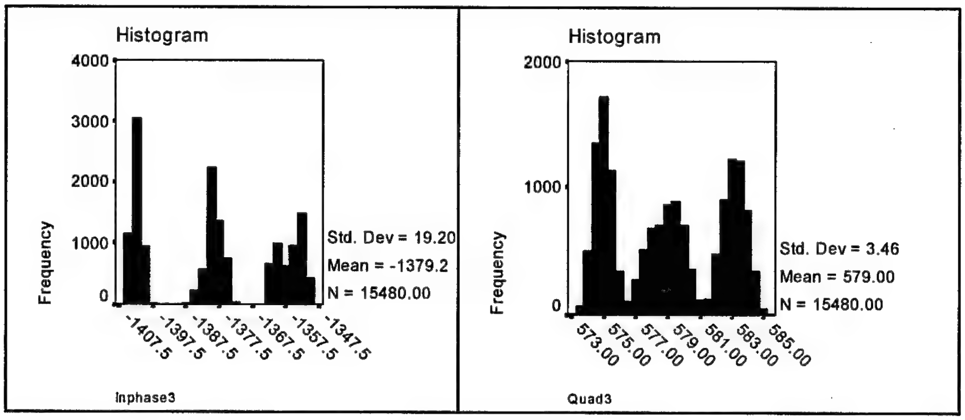

Figure 46. In-phase and quadrature histograms for 57-mm mortar at 330 Hz

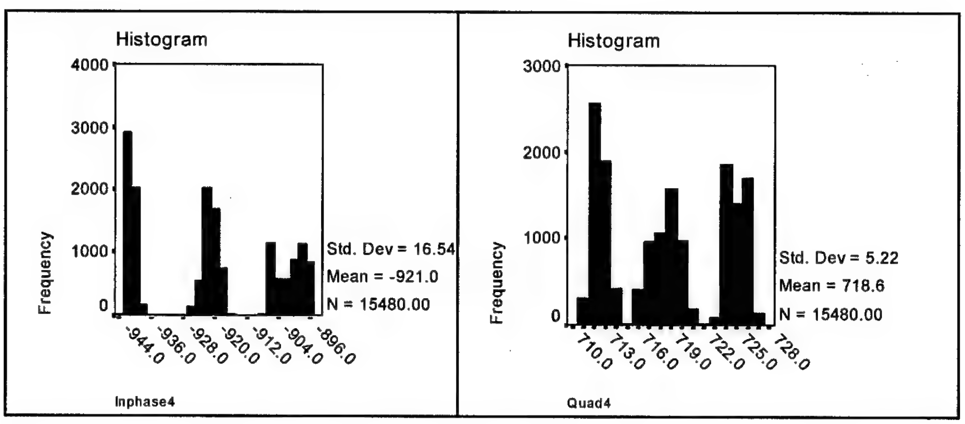

Figure 47. In-phase and quadrature histograms for 57-mm mortar at 930 Hz

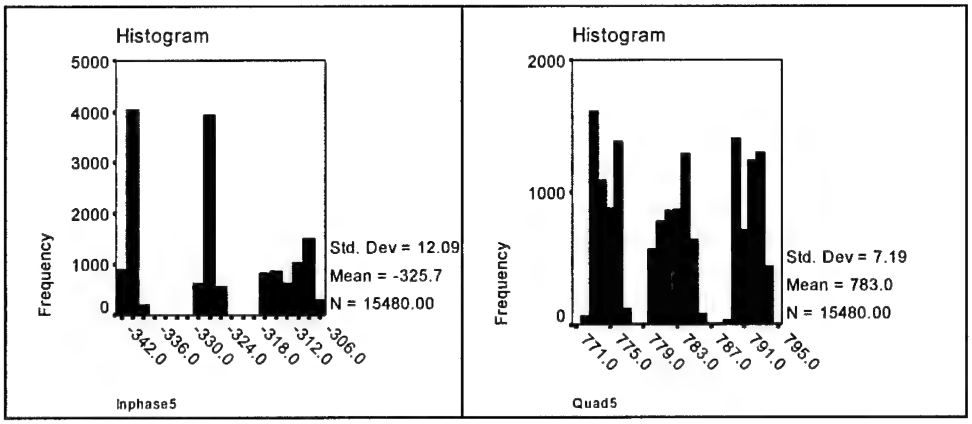

Figure 48. In-phase and quadrature histograms for 57-mm mortar at 2,790 Hz

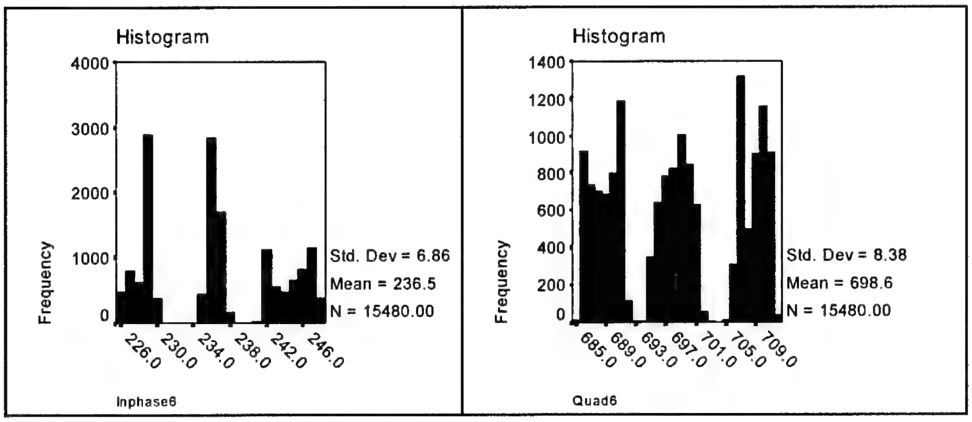

Figure 49. In-phase and quadrature histograms for 57-mm mortar at 8,190 Hz

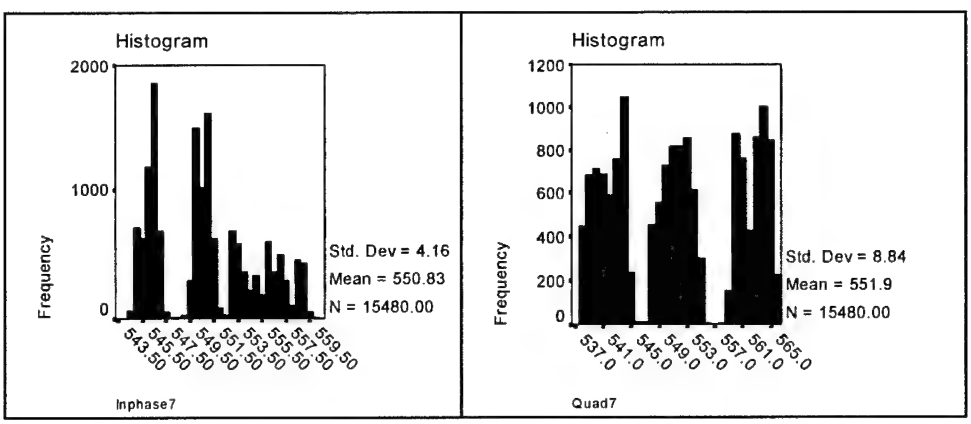

Figure 50. In-phase and quadrature histograms for 57-mm mortar at 20,010 Hz

Table 7
Statistical Information on Fixed Target Variation
Sample Size N = 15,480

Description	Component	Frequency	Mean	Std. Deviation
Background	In-phase1	90	0.0342	0.15307
	In-phase2	150	0.0179	0.091938
	In-phase3	330	0.0213	0.04845
	In-phase4	930	0.0331	0.03764
	In-phase5	2,790	0.0922	0.07864
	In-phase6	8,190	0.3074	0.25669
	In-phase7	20,010	-3.3078	2.14604
	Quad1	90	0.0137	0.15560
	Quad2	150	-.0000155	0.09292
	Quad3	330	-.00406	0.04263
	Quad4	930	0.0057	0.03581
	Quad5	2,790	-0.0158	0.13205
	Quad6	8,190	-0.8627	0.94256
	Quad7	20,010	-8.6170	6.78427
20-mm	In-phase1	90	-78.5324	6.7391
	In-phase2	150	-75.8057	6.5315
	In-phase3	330	-69.5563	6.3570
	In-phase4	930	-57.7184	6.1737
	In-phase5	2,790	-41.1624	6.0193
	In-phase6	8,190	-34.5964	6.0938
	In-phase7	20,010	-90.0381	8.0931
	Quad1	90	7.4923	1.5388
	Quad2	150	9.9834	0.7586
	Quad3	330	13.9623	0.4118
	Quad4	930	18.4170	0.3942
	Quad5	2,790	18.1551	0.6143
	Quad6	8,190	4.0144	1.1135
	Quad7	20,010	-15.8804	1.8402
57-mm	In-phase1	90	-1782.262	21.3220
	In-phase2	150	-1645.632	20.5687
	In-phase3	330	-1379.235	19.2048
	In-phase4	930	-920.9837	16.5396
	In-phase5	2,790	-325.7171	12.0936
	In-phase6	8,190	23.4787	6.8598
	In-phase7	20,010	550.8331	4.1577
	Quad1	90	365.1280	2.8266
	Quad2	150	448.8472	2.5750
	Quad3	330	578.9956	3.4596
	Quad4	930	718.6377	5.2193
	Quad5	2,790	782.9586	7.1893
	Quad6	8,190	698.6334	8.3765
	Quad7	20,010	551.8812	8.8383

Comparison of Data Points with Calibration Data

To determine how closely the data points acquired near targets during the demonstration match the corresponding calibration signatures, the data points within a 1-m box centered on each target were extracted. They were compared to the calibration signature for the same ordnance type as the target at all inclination angles. The best matching angle was selected. The exact inclination angle of the target was not used because the position of the sensor relative to the target during the demonstration varied from point to point, unlike the calibration data where the sensor was always directly above the target. Tables 8, 9, and 10 summarize the results of this comparison. Targets for which no calibration data were available are not included. Plots showing the comparison between each data point and the calibration signature, as well as the locations of the points relative to the target, are shown for every target in Appendix B. Code listings for the programs are given in Appendix C.

Table 8
Comparison of Data Points with Calibration Signatures in Area 1

Target ID	Type	Depth cm	Inclination angle, deg	Number of Points	Minimum Error	Maximum Error	Mean Error	Std Dev of Error
1-86	4.2-in.	20	45	8	0.0100	0.1095	0.0491	0.0361
1-88	60-mm	35	0	12	0.0235	0.6212	0.1954	0.1850
1-90	4.2-in.	35	0	15	0.0165	0.4299	0.0968	0.1209
1-92	81-mm	20	20	11	0.0425	0.2417	0.0873	0.0592
1-94	81-mm	25	55	5	0.0890	0.3049	0.1846	0.0785
1-96	81-mm	15	35	10	0.0095	0.3622	0.0803	0.1099
1-98	60-mm	10	20	8	0.0097	0.1492	0.0574	0.0483
1-100	60-mm	20	30	7	0.0239	0.4182	0.2251	0.1611
1-102	81-mm	25	45	7	0.0084	0.2707	0.0865	0.0902
1-104	81-mm	35	0	7	0.0299	0.1377	0.0709	0.0404
1-106	60-mm	25	35	8	0.0513	0.2855	0.1362	0.0702
1-108	60-mm	20	45	8	0.0258	0.5122	0.2734	0.1695
1-112	20-mm	10	10	9	0.1090	0.3726	0.2028	0.0860
1-114	20-mm	15	20	11	0.2824	0.5345	0.3857	0.0841
1-116	20-mm	15	0	6	0.2400	0.5572	0.4014	0.1324
1-117	152-mm	90	45	18	0.0760	0.6827	0.2678	0.1644
1-119	152-mm	40	30	12	0.0224	0.1922	0.0996	0.0508
1-121	155-mm	50	0	9	0.0119	0.1403	0.0391	0.0390
1-123	20-mm	0	90	10	0.1027	0.4538	0.2964	0.1240
1-124	20-mm	0	-90	31	0.2523	0.6976	0.3938	0.1128
1-126	57-mm	20	30	10	0.2184	0.6329	0.5026	0.1241
1-128	20-mm	10	0	11	0.0438	0.2624	0.1512	0.0799
1-132	57-mm	25	0	9	0.0247	0.4117	0.1392	0.1157
1-134	20-mm	5	30	10	0.0758	0.6445	0.4085	0.1999
1-136	155-mm	50	75	5	0.0267	0.0686	0.0487	0.0158
1-138	57-mm	15	45	9	0.0302	0.2422	0.1038	0.0813
1-140	20-mm	5	15	9	0.1186	0.467	0.2615	0.1275
1-142	57-mm	15	45	8	0.0058	0.038	0.0235	0.0119
1-146	20-mm	5	0	14	0.1084	0.5391	0.3326	0.1517
1-147	57-mm	25	0	6	0.0114	0.4985	0.2442	0.2105
1-148	20-mm	10	45	8	0.1830	0.6268	0.3457	0.1805
1-149	2.75-in.	50	55	8	0.0160	0.2399	0.1055	0.0726
1-150	2.75-in.	70	45	40	0.0357	0.5201	0.1944	0.1025
1-152	2.75-in.	15	0	9	0.0458	0.109	0.0772	0.0243
1-153	2.75-in.	76	90	9	0.0767	0.6012	0.4352	0.1697

Note: To convert inches to meters, multiply by 0.0254.

Table 9 Comparison of Data Points with Calibration Signatures in Area 2								
Target ID	Type	Depth (cm)	Inclination angle	Number of Points	Minimum Error	Maximum Error	Mean Error	Std Dev of Error
2-112	81-mm	10	90	3	0.0096	0.0643	0.0289	0.0307
2-114	81-mm	20	-90	8	0.0070	0.2249	0.0690	0.0684
2-116	81-mm	30	0	8	0.0122	0.1463	0.0606	0.0463
2-118	60-mm	35	45	9	0.1200	0.5099	0.2611	0.1142
2-120	60-mm	30	0	8	0.0424	0.3254	0.1130	0.0932
2-122	60-mm	10	30	10	0.0232	0.5161	0.1351	0.1592
2-124	60-mm	20	10	8	0.0188	0.6151	0.1506	0.2004
2-126	81-mm	35	45	7	0.0274	0.1084	0.0570	0.0323
2-128	60-mm	10	20	8	0.0046	0.0888	0.0364	0.0279
2-130	81-mm	70	0	10	0.0159	0.3097	0.0759	0.0882
2-131	81-mm	25	0	7	0.0057	0.0379	0.0200	0.0115
2-134	4.2-in.	40	0	8	0.0118	0.0377	0.0257	0.0112
2-136	20-mm	5	10	8	0.2054	0.6724	0.4012	0.1689
2-138	20-mm	5	15	7	0.2121	0.5602	0.3455	0.1183
2-142	152-mm	91	45	11	0.1341	0.3596	0.2438	0.0717
2-144	152-mm	45	30	7	0.0642	0.3177	0.1472	0.1082
2-146	20-mm	0	90	18	0.0610	0.6574	0.3535	0.1625
2-148	20-mm	0	-90	8	0.1893	0.6583	0.4192	0.1874
2-150	20-mm	10	0	11	0.0284	0.6097	0.3680	0.1845
2-152	57-mm	25	0	10	0.0224	0.2997	0.1039	0.0993
2-154	57-mm	20	45	11	0.0252	0.2989	0.1201	0.0891
2-156	155-mm	102	90	10	0.0843	0.5366	0.1896	0.1412
2-158	20-mm	10	20	9	0.0276	0.5122	0.1775	0.1465
2-160	57-mm	35	40	9	0.0285	0.5212	0.2257	0.1471
2-161	155-mm	75	30	7	0.0215	0.1410	0.0649	0.0430
2-164	2.75-in.	60	10	4	0.0660	0.1433	0.1047	0.0316
2-166	2.75-in.	75	20	4	0.2687	0.5892	0.4617	0.1464
Note: To convert inches to meters, multiply by 0.0254.								

Table 10 Comparison of Data Points with Calibration Signatures in Area 3								
Target ID	Type	Depth (cm)	Inclination angle	Number of Points	Minimum Error	Maximum Error	Mean Error	Std Dev of Error
3-68	60-mm	20	90	10	0.0149	0.3716	0.1308	0.1373
3-70	81-mm	25	0	9	0.0158	0.0521	0.0301	0.0138
3-72	60-mm	25	30	10	0.0202	0.4133	0.2271	0.1573
3-74	60-mm	30	45	10	0.0152	0.0884	0.0390	0.0231
3-76	81-mm	20	-90	4	0.0065	0.0454	0.0261	0.0185
3-78	60-mm	35	40	9	0.0213	0.4177	0.1242	0.1205
3-80	81-mm	25	0	11	0.0111	0.1795	0.0350	0.0503
3-82	60-mm	20	15	7	0.0181	0.3424	0.1001	0.1114
3-84	81-mm	25	0	9	0.1225	0.1694	0.1452	0.0137
3-86	20-mm	1	90	8	0.1028	0.3071	0.1919	0.0804
3-88	20-mm	1	0	5	0.0545	0.4379	0.1992	0.1542
3-90	20-mm	15	0	9	0.0732	0.5454	0.2431	0.1550
3-92	20-mm	15	30	6	0.0622	0.5500	0.2650	0.1949
3-94	57-mm	35	0	8	0.0462	0.2992	0.1548	0.0933
3-96	57-mm	25	20	8	0.0185	0.3410	0.0764	0.1088
3-100	152-mm	91	35	10	0.1582	0.4296	0.2549	0.0835
3-102	155-mm	120	20	8	0.2182	0.5247	0.3507	0.1185
3-106	2.75-in.	50	30	11	0.0562	0.4900	0.2228	0.1468
Note: To convert inches to meters, multiply by 0.0254.								

Strong signatures

The minimum error column of Tables 8, 9, and 10 shows the error in fit of the data point near the target that most closely matches the calibration signature for the ordnance type of the target. Figures 51 through 58 show examples of data points near targets of each of the different ordnance types that closely match the corresponding calibration signatures.

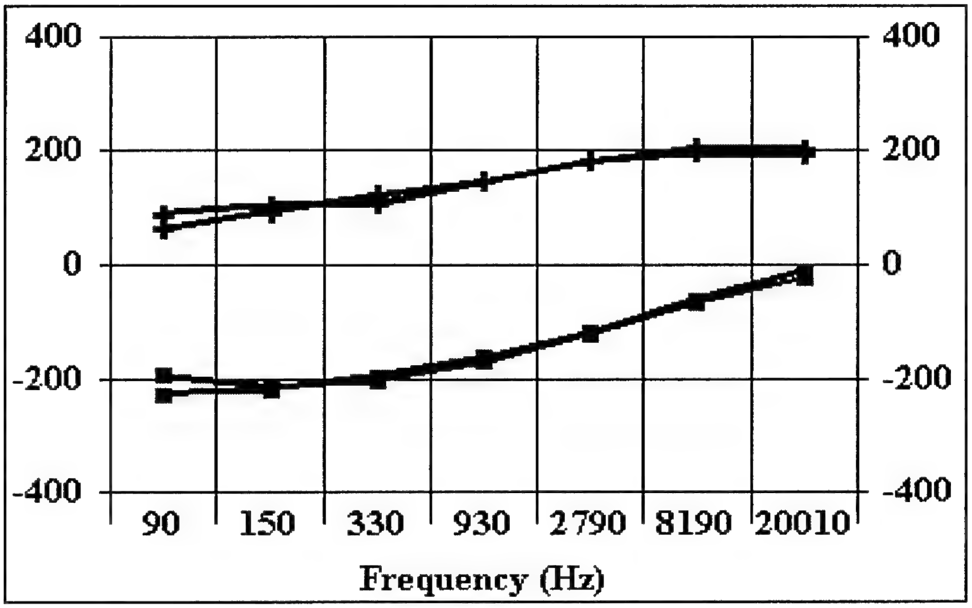

Figure 51. Best matching point for target 2-158 (20-mm projectile)

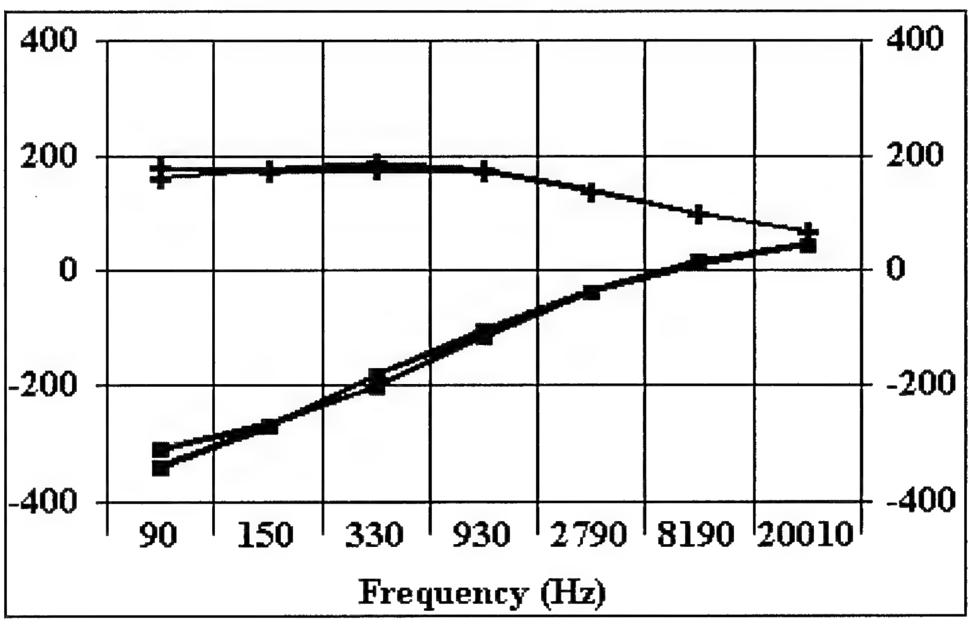

Figure 52. Best matching point for target 3-96 (57-mm mortar)

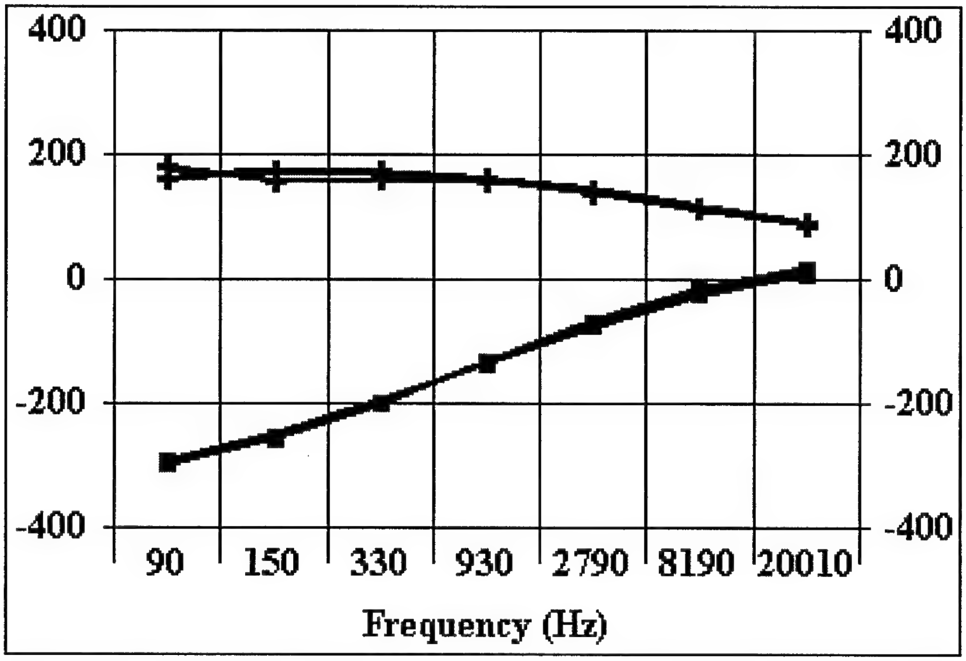

Figure 53. Best matching point for target 3-74 (60-mm mortar)

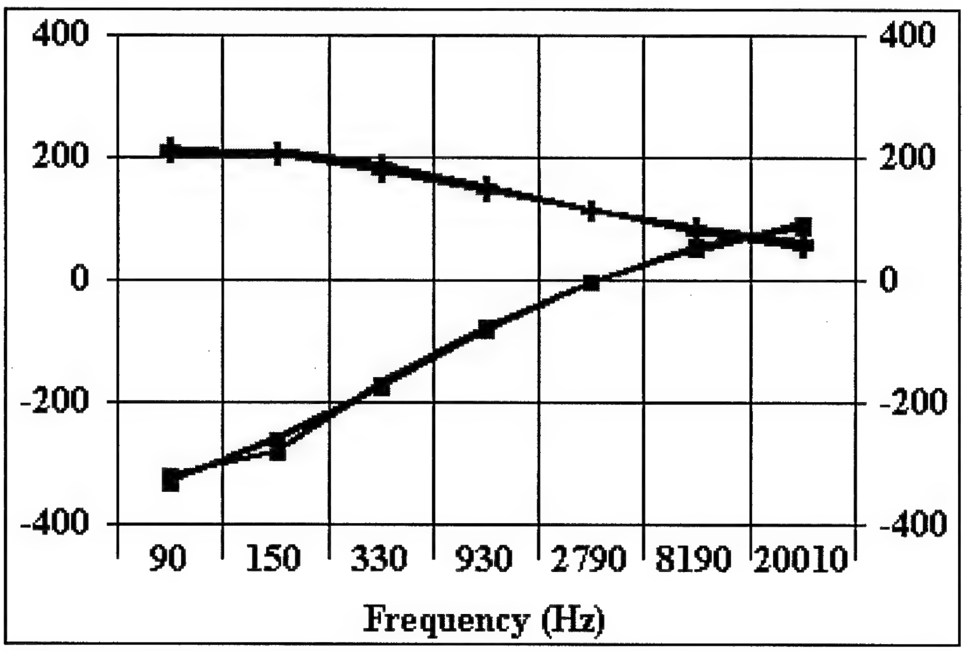

Figure 54. Best matching point for target 1-149 (2.75-in. rocket) (To convert inches to meters, multiply by 0.0254)

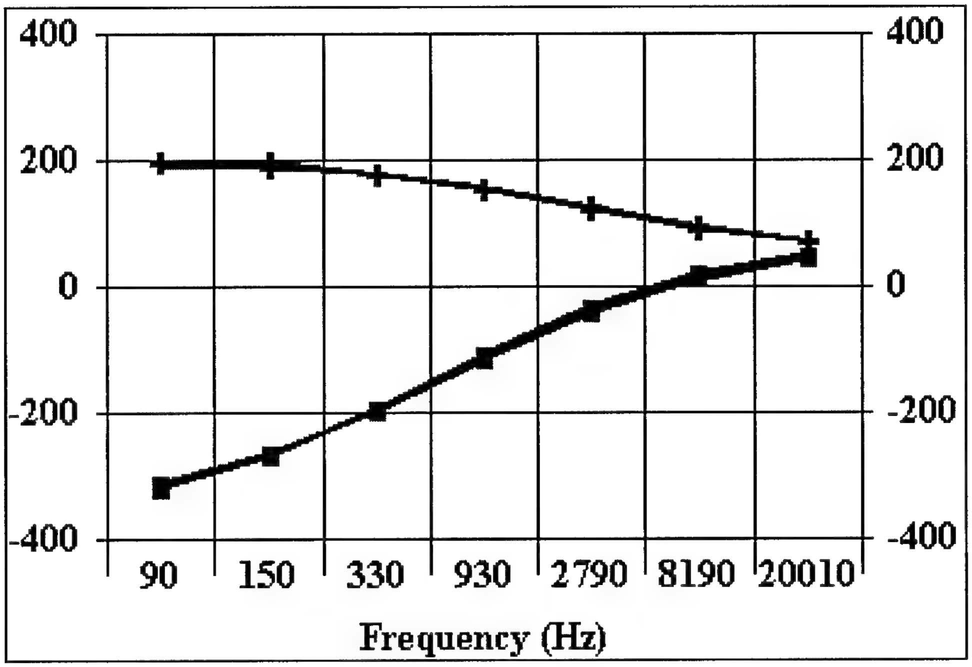

Figure 55. Best matching point for target 1-96 (81-mm mortar)

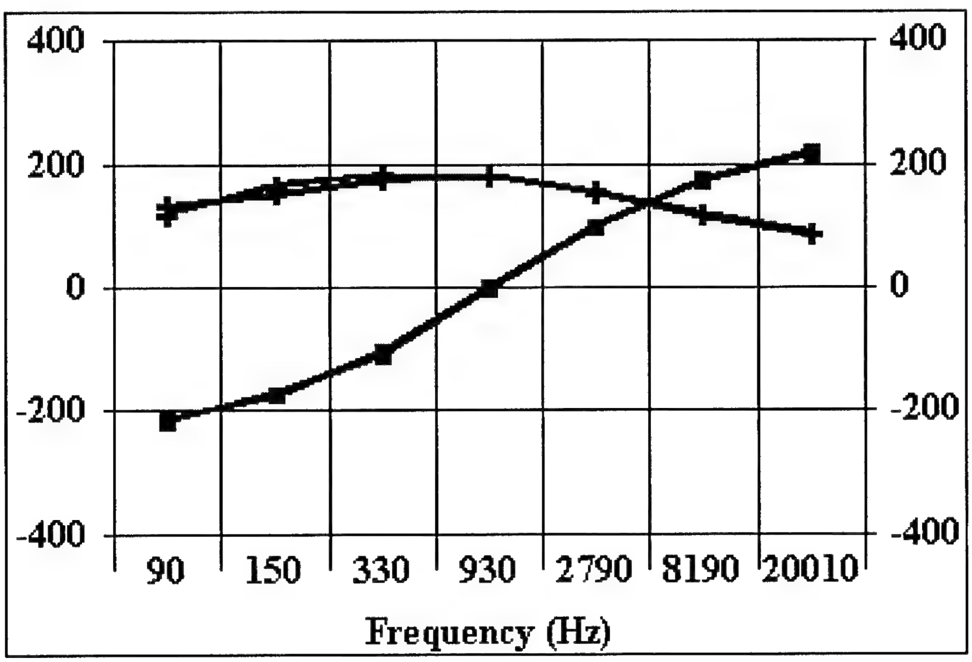

Figure 56. Best matching point for target 2-134 (4.2-in. mortar) (To convert inches to meters, multiply by 0.0254)

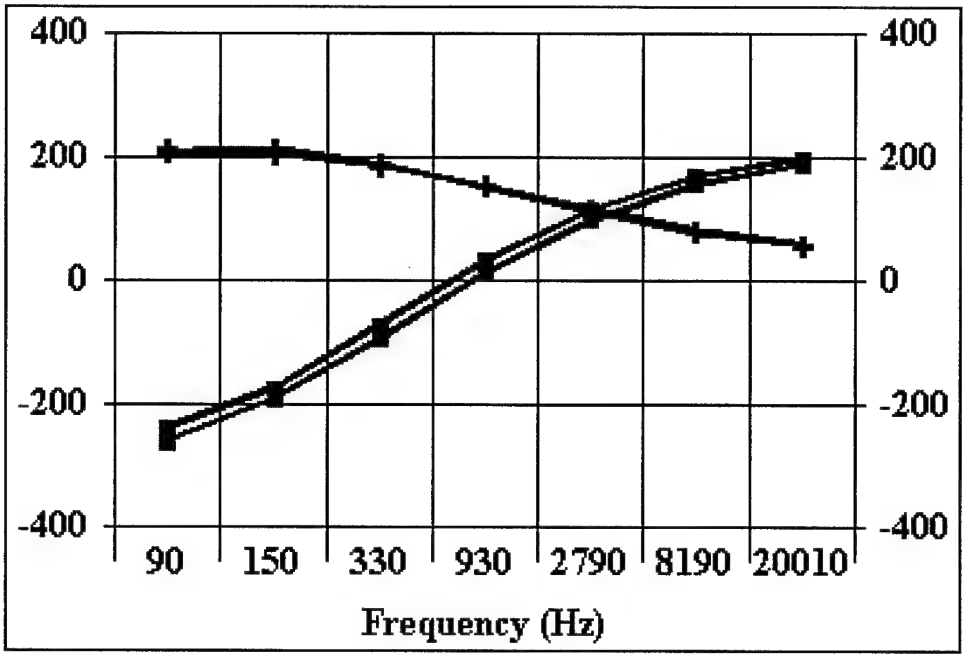

Figure 57. Best matching point for target 1-119 (152-mm projectile)

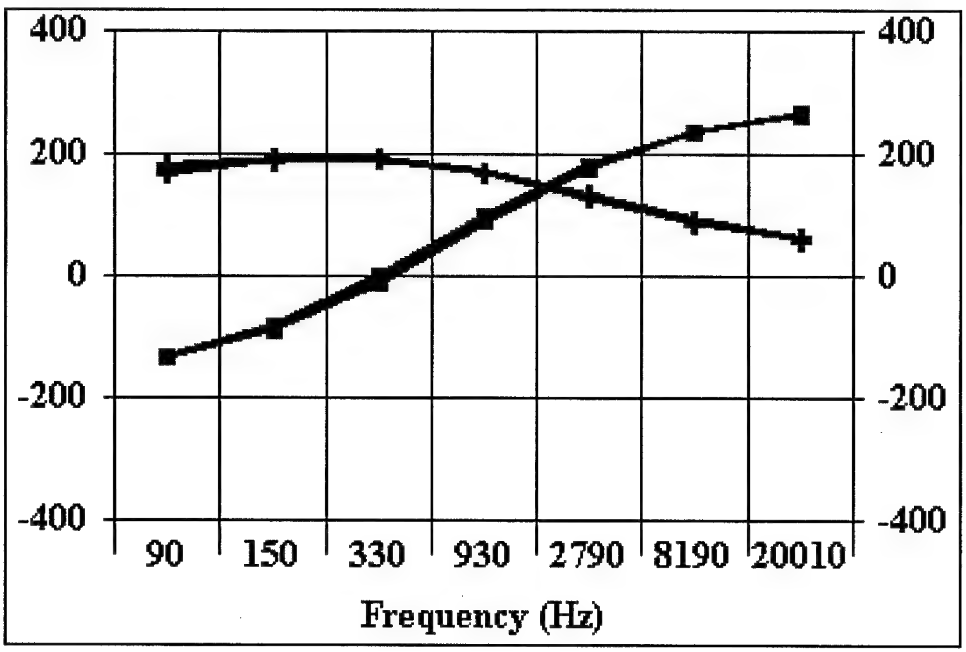

Figure 58. Best matching point for target 1-121 (155-mm projectile)

Weak signatures

A total of 19 targets had no points near them with an error in fit less than 0.1. Twelve of these targets were 20-mm projectiles and the weak signatures were likely a result of the small size of the target. The few data points with good signatures near 20-mm projectiles were very close to the target (within 0.25 m). Targets 2-150 and 2-158 are examples of 20-mm targets that had data points with good signatures very near the target. In some cases, the sensor did not get that close to a target. However, even when the sensor did get very close to a 20-mm projectile, the signature was not necessarily strong enough to classify it correctly. Target 1-124, with a total of 12 data points within 0.25 m, but none with a good signature, is a good example of this.

Figures 59 through 65 show the best matching data points for the seven larger targets that had no points with error in fit less than 0.1. All but two of these targets, 3-84 and 1-126, were among the deepest targets of their type emplaced at JPG, and their weak signatures are probably the result of their depth. The in-phase data for target 3-84 consists of large magnitude values of a nearly constant value for every frequency, possibly because of a recording error of some kind. Figure 59 shows that the quadrature data for the target matches the calibration data very well. The data points for target 1-126, a 57-mm mortar at a depth of 20 cm, had an average magnitude of only 62, a much weaker signal than for similar targets at similar depths. The total magnitude of a data point is the sum of the absolute values of the in-phase and quadrature measurements for all frequencies.

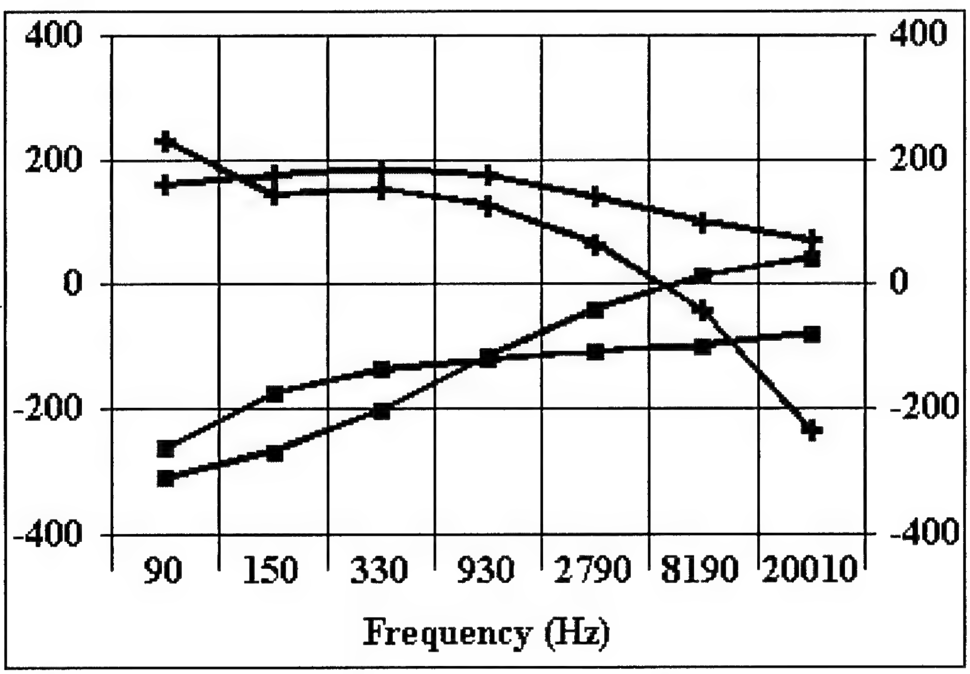

Figure 59. Best matching point for target 1-126 (57-mm mortar)

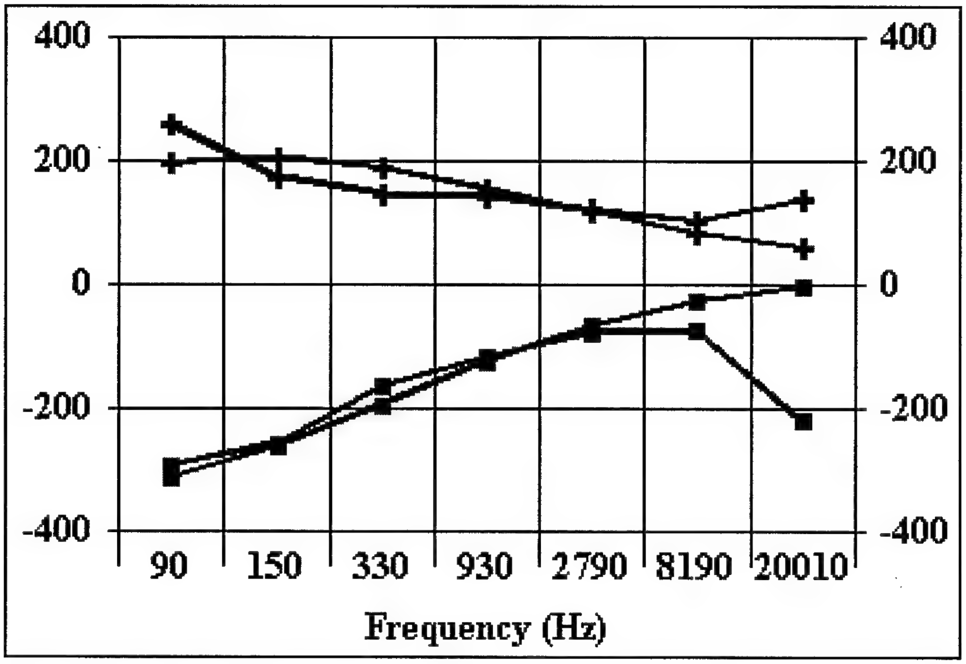

Figure 60. Best matching point for target 2-118 (60-mm mortar)

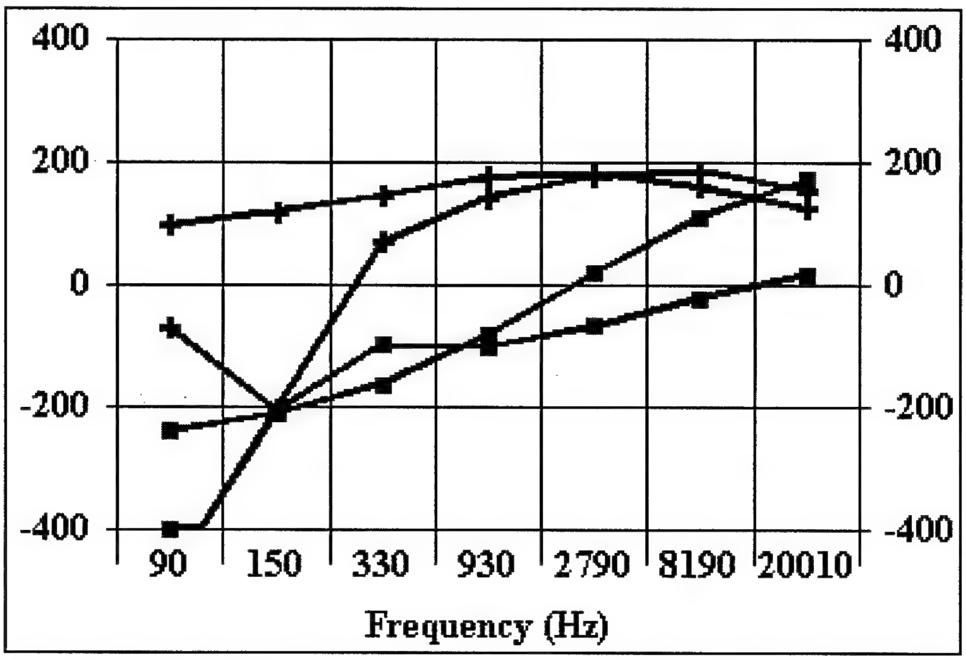

Figure 61. Best matching point for target 2-166 (2.75-in. rocket) (To convert inches to meters, multiply by 0.0254)

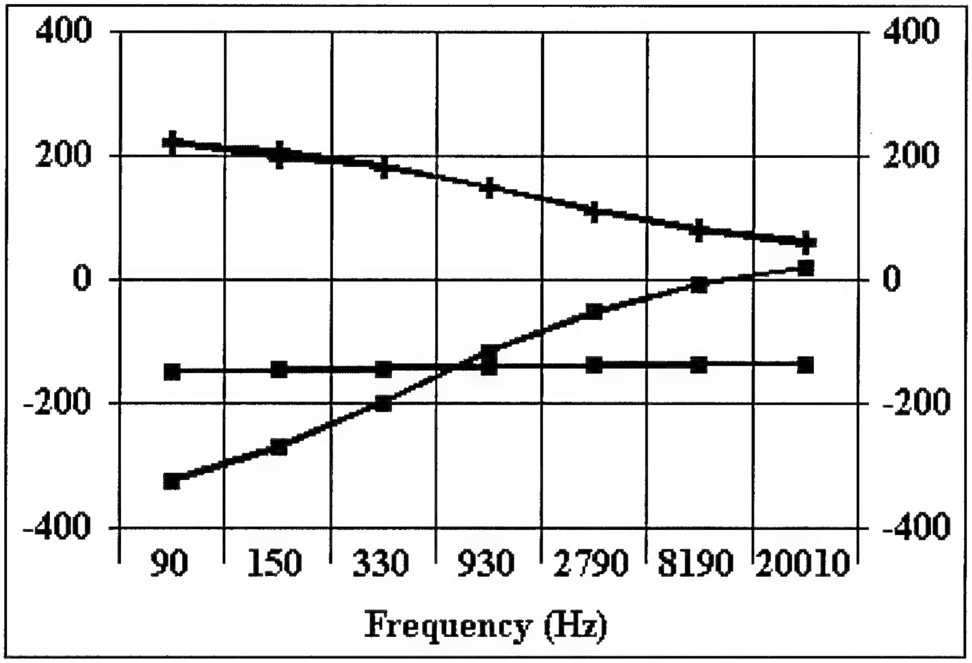

Figure 62. Best matching point for target 3-84 (81-mm mortar)

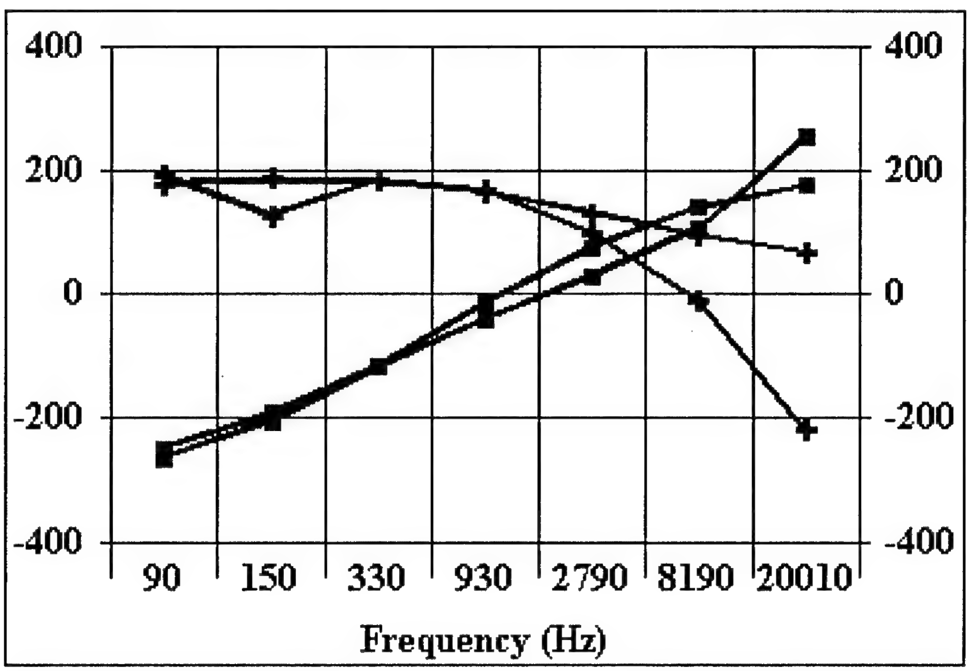

Figure 63. Best matching point for target 3-100 (152-mm projectile)

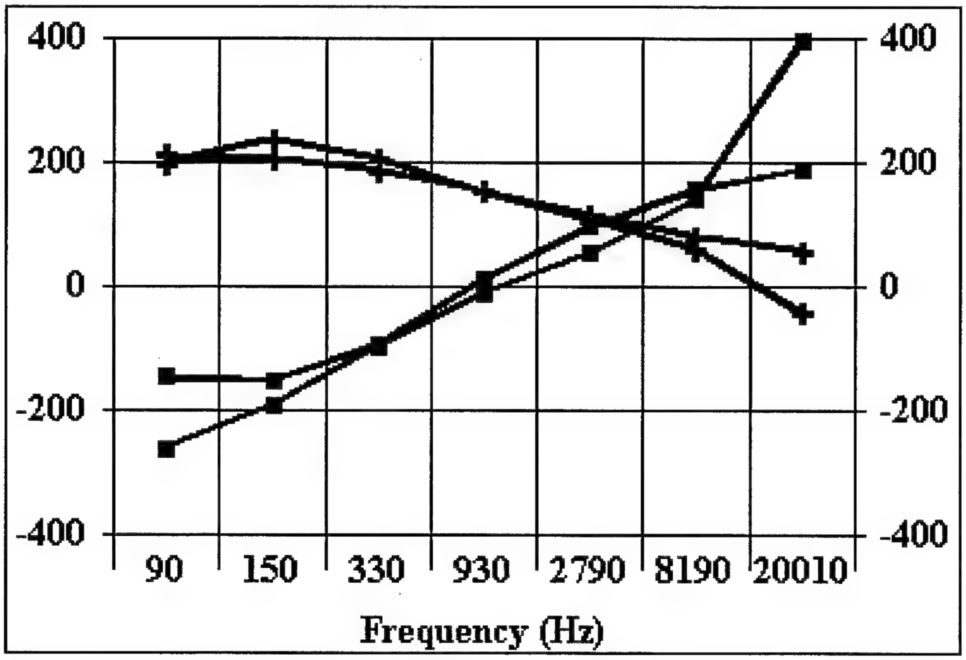

Figure 64. Best matching point for target 2-142 (152-mm projectile)

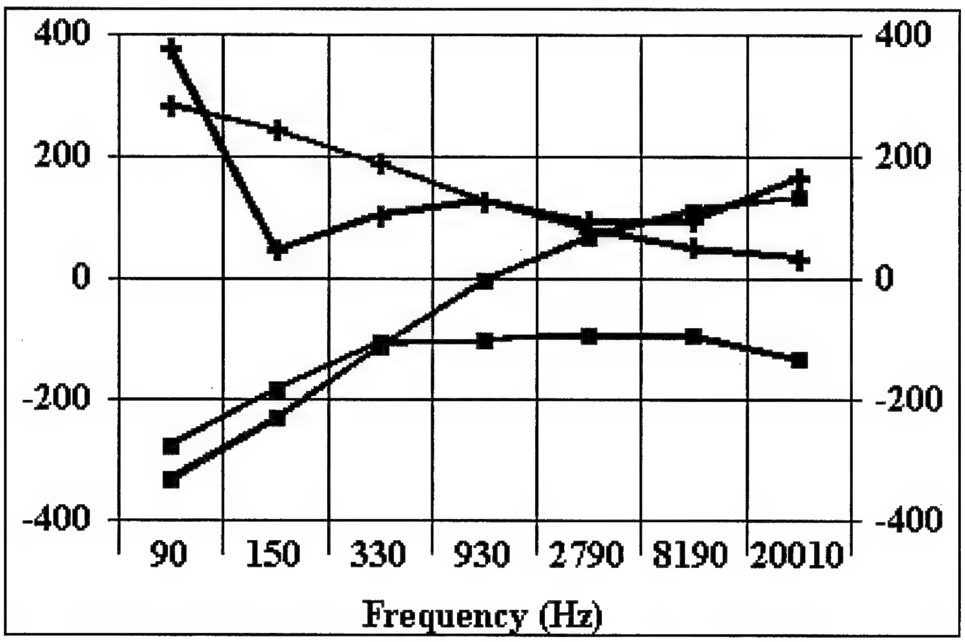

Figure 65. Best matching point for target 3-102 (155-mm projectile)

Depth effects

The effect of depth on the signal strength of the GEM-3 is apparent in **Error! Reference source not found.**, which shows the average total magnitude of data points within a 1-m box centered on the target vs. target depth for the 155-mm projectiles, 81-mm mortars, and 60-mm mortars emplaced at JPG. The total magnitude of a data point is the sum of the absolute values of the in-phase and quadrature measurements for all frequesncies. For all three ordnance types, the signal strength decreases sharply with increasing depth. The effect of target depth on the classification of targets can best be illustrated by examining the data for the 155-mm projectiles, which were the largest targets in the demonstration. A total of five 155-mm projectiles were included in the demonstration at depths of 50, 75, 102, and 120 cm. The data points near the two 155-mm projectiles buried at 50 cm, targets 1-121 and 1-136, had an average total magnitude of over 2,000, and nearly all of them matched the calibration signatures quite well. The points near target 2-161, buried at 75 cm, have an average magnitude of 396 and also match the calibration signatures well. The data points near the two deepest 155-mm projectiles, targets 2-156 and 3-102, have an average magnitude of less than 200. The deepest, target 3-102, has no points with a recognizable signature. Target 2-156 has three points that match the calibration signature for a 155-mm projectile with an error just under 0.1, although they match other ordnance types slightly better. From those data, it appears that reliable classification of 155-mm projectiles at depths greater than 1 m is unlikely. Classification of smaller ordnance types will suffer from weak signal at shallower depths. Other targets that produced weak signatures because of depth include three 152-mm projectiles, targets 1-117, 2-142, and 3-100, all at depths of approximately 90 cm and two 0.07-m (2.75-in.) rockets, targets 1-153 and 2-166, both at depths of 76 cm. Three targets, [2-132 (0.13 m (5-in.) projectile at a depth of 91 cm), 2-140 (105-mm projectile at a depth of 70 cm), and 3-104 (76-mm projectile at a depth of 76 cm)], for which there were no calibration data also appeared to be too deep for classification. Targets of these types at shallower depths were classified as targets of similar size for which calibration data were available.

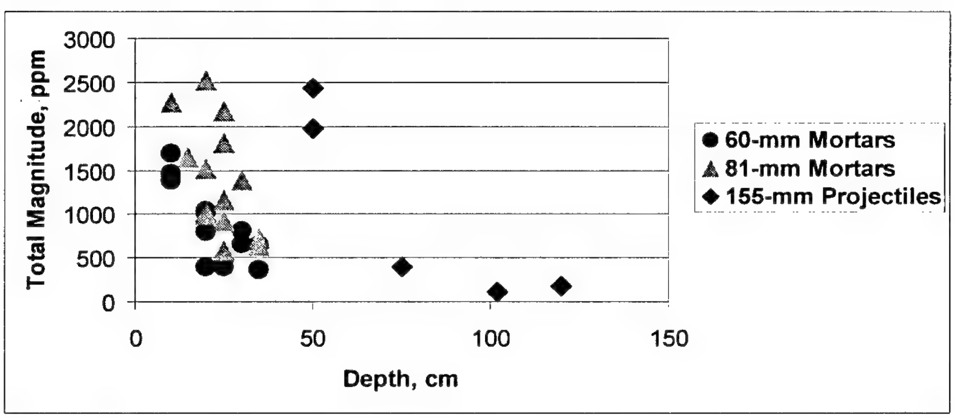

Figure 66. Average magnitude vs. depth for selected ordnance types

Errors by frequency

For many data points, the error in fit with the calibration data was dominated by the measurement for a single frequency. In such cases, excluding that frequency from the calculations produced a much closer fit of the point with the calibration data. An example of this is shown in Figures 67 and 68. The 90-Hz data are included in the graph in Figure 68 for reference but not included in the magnitude normalization or error calculations. Using all frequencies, as shown in Figure 67, the error in fit was calculated to be 0.1369, while excluding the 90 Hz data reduced the error to only 0.0645.

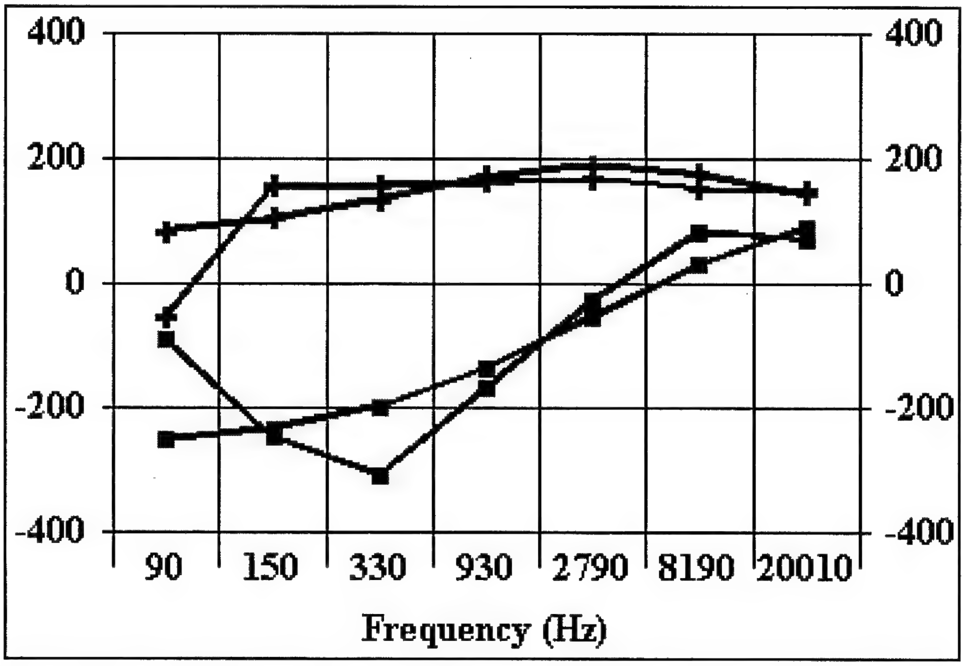

Figure 67. Calibration match with all frequencies for target 1-132 (57-mm mortar)

Although 90 Hz was the most likely frequency to cause problems, it was not the only one that did. The error in fit of the data points shown in a previous section for targets 2-118, 2-142, and 3-100 are dominated by the 20,010 Hz measurement. Excluding that frequency brings the error in fit for all three data points to less than 0.08. In almost all cases, data points with large errors in one frequency were relatively low in magnitude.

To determine the overall contributions of particular frequencies to the error between data points and calibration signatures throughout the data set, the differences between all the data points and corresponding calibration signatures for each frequency were averaged. The results are shown in Figure 69. The lowest frequency, 90 Hz, has a substantially larger average difference than the other frequencies.

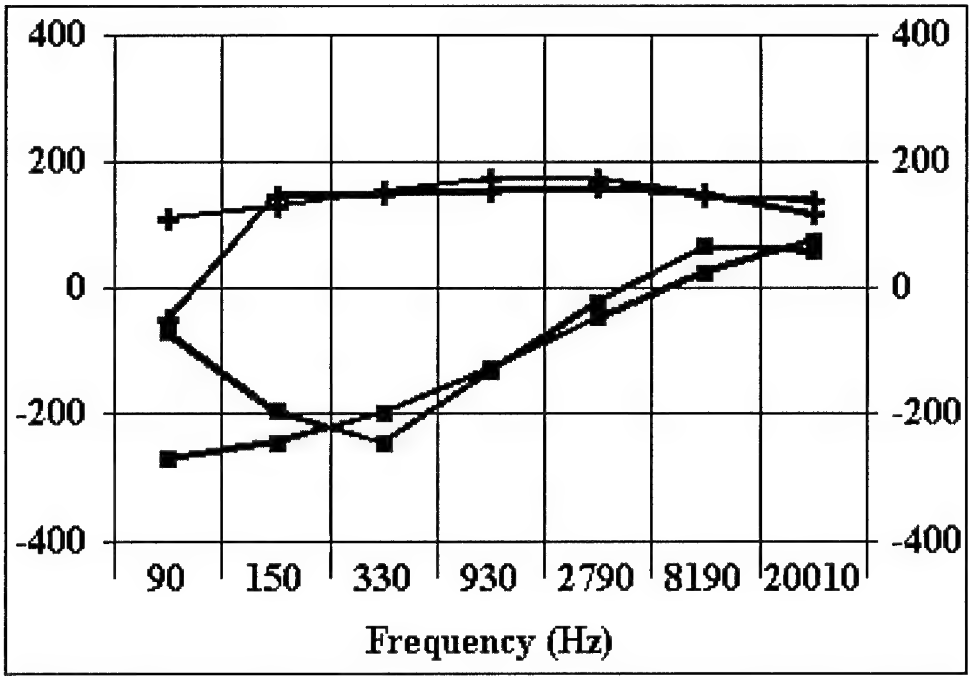

Figure 68. Calibration match without 90 Hz for target 1-132 (57-mm mortar)

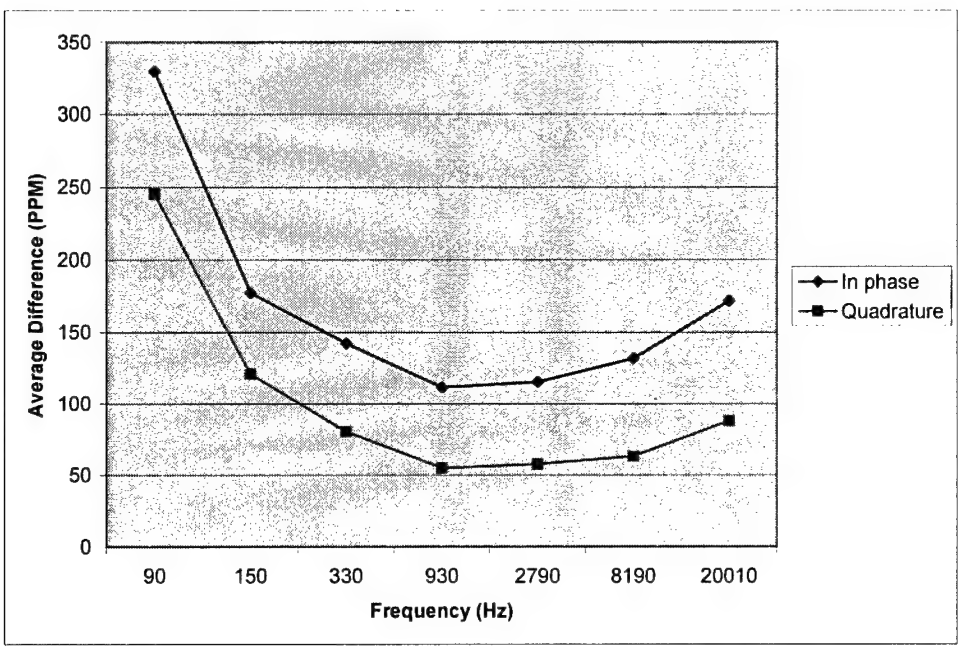

Figure 69. Average difference by frequency

Classification of Targets

Figure 70 through 72 show the calibration data for all the different ordnance types at 0, 90, and -90 deg, respectively. These data have been normalized to the same total quadrature and the same total in-phase responses so that the relative responses of each ordnance type at each of the seven frequencies can be compared. Some of the ordnance types have very similar signatures to each other. A simple classification procedure was applied to the JPG data to examine the separability of the different ordnance types from each other. Each target was classified using the single data point with the greatest magnitude of the points near the target. The error in fit between the data point and each ordnance type at each inclination angle was calculated. The target was classified as the ordnance type that had the lowest error in fit at any inclination angle. The results are shown in Table 11. Overall, 41.9 percent (39/93) of the targets were classified correctly. Excluding the three ordnance types for which no calibration data were available, 48.8 percent (39/80) of the targets were correctly classified, including 60.1 percent (20/33) of the mortars, 40.0 percent (16/40) of the projectiles, and 42.9 percent (3/7) of the rockets. Because of the very similar signatures of some of the targets, a more informative way to look at the classification matrix would be to group the targets by size as shown in Table 12. With aggregation by size, 71.0 percent (66/93) of the targets are classified in the correct group, including 78.1 percent (56/73) of the medium and large targets.

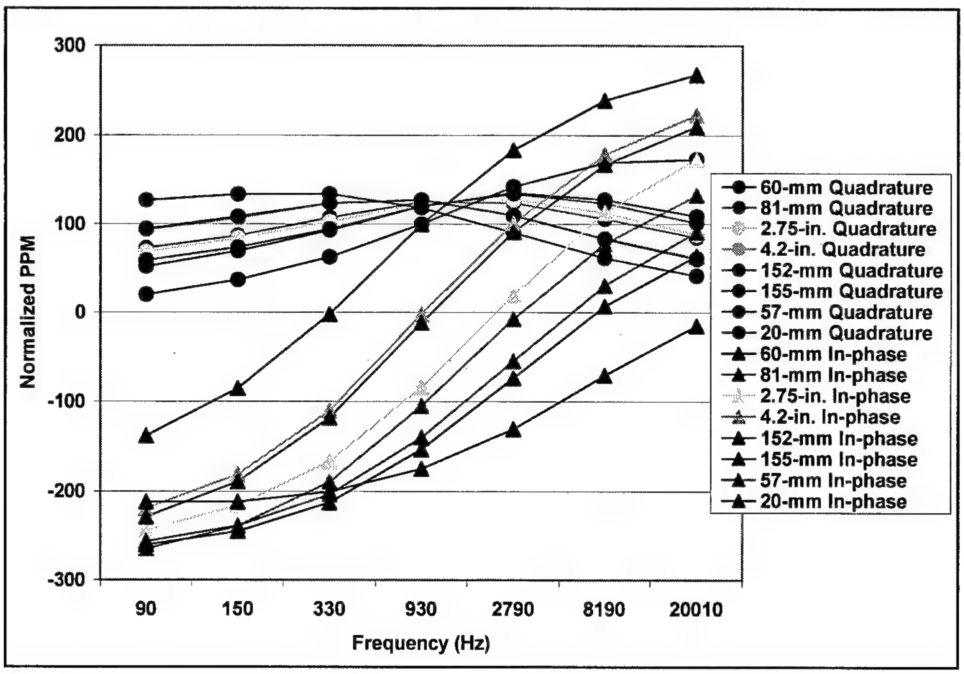

Figure 70. Calibration data with targets at 0-deg inclination

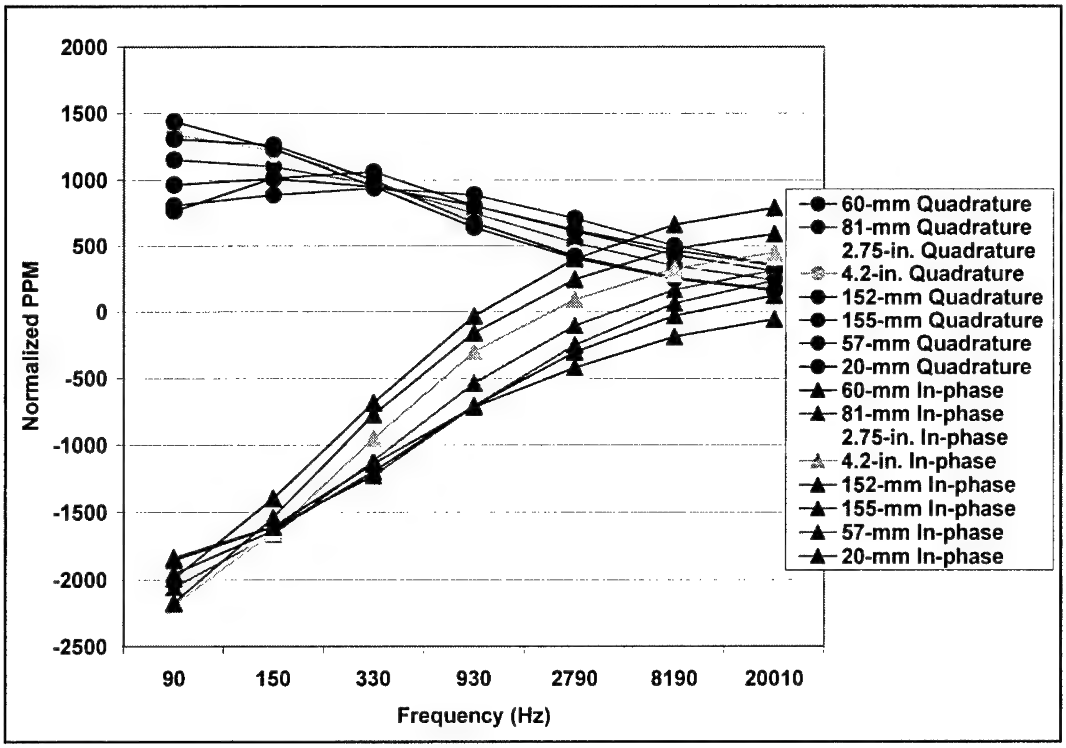

Figure 71. Calibration data with targets at 90 deg inclination (noseup)

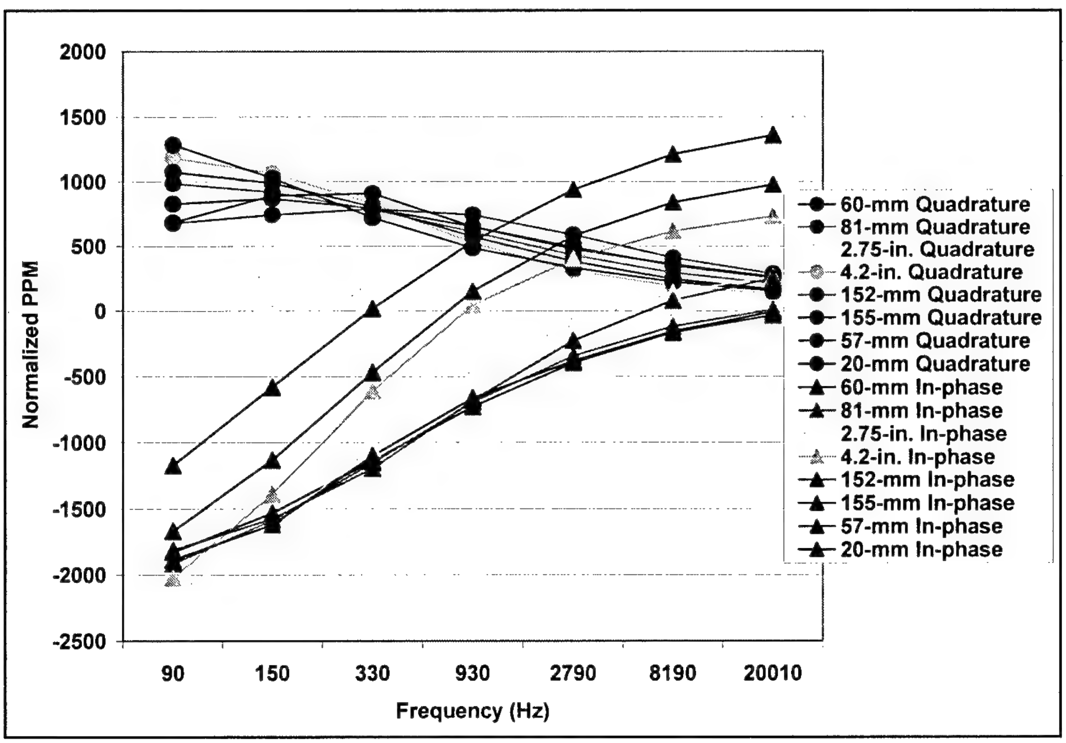

Figure 72. Calibration data with targets at -90 deg inclination (nosedown)

Table 11
Classification Matrix Using All Frequencies

	Ordnance Type												
Classification	20-mm	57-mm	60-mm	2.75-in.	76-mm	81-mm	105-mm	4.2-in.	5.0-in.	152-mm	155-mm	FA	Total
20-mm	9	1	3	2	0	0	0	0	0	0	0	0	15
57-mm	1	4	2	0	0	3	0	0	0	0	0	0	10
60-mm	3	3	8	2	0	1	0	0	0	0	1	0	18
2.75-in	4	0	0	3	1	2	0	0	0	1	1	0	12
76-mm	0	0	0	0	0	0	0	0	0	0	0	0	0
81-mm	0	1	1	0	1	9	1	0	0	1	0	0	14
105-mm	0	0	0	0	0	0	0	0	0	0	0	0	0
4.2-in	0	0	0	0	1	0	0	3	0	0	0	0	4
5.0-in	0	0	0	0	0	0	0	0	0	0	0	0	0
152-mm	0	1	0	0	0	0	0	0	1	0	0	0	2
155-mm	3	0	1	0	2	0	3	0	3	3	3	0	18
Nonord	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	20	10	15	7	5	15	4	3	4	5	5	0	93
%classified	45.0	40.0	53.3	42.9	0.0	60.0	0.0	100.0	0.0	0.0	60.0		

Note: To convert inches to millimeters, multiply by 25.4.

Table 12
Classification Matrix Using All Frequencies Aggregated by Ordnance Size

	Ordnance Type		
Classification	20-mm	57 to 81-mm	105 to 155-mm
20-mm	9	6	0
57- to 81-mm	8	41	5
105- to 155-mm	3	5	16
Total	20	52	21
% classified	45.0	78.8	76.2

Because of the larger average difference between the data points and the calibration data for the 90 Hz data, that frequency was excluded from the calculations to see if the results would improve. Tables 13 and 14 show the complete and aggregated results of this classification, respectively. Also, because of reports from Geophex that both the 90 Hz and 150 Hz data were noisy, a classification was performed excluding both of those frequencies. The complete and aggregated classification matrices excluding 90 and 150 Hz are shown in and Tables 15 and 16, respectively. The results did not change significantly in either of these classifications compared with the classification using all frequencies. A total of 40 targets were classified correctly in each of them, one more than were classified correctly using all frequencies. Several targets changed classifications when the 90 Hz data were excluded, but the gains and losses essentially canceled each other out. Viewing the data for individual targets indicates that excluding the 90 Hz data reduces the errors of data points

Table 13
Classification Matrix without 90 Hz Data

	Ordnance Type												
Classification	20-mm	57-mm	60-mm	2.75-in.	76-mm	81-mm	105-mm	4.2-in.	5.0-in.	152-mm	155-mm	FA	Total
20-mm	9	1	3	3	0	2	1	0	0	2	1	0	22
57-mm	3	4	2	0	0	3	0	0	0	0	0	0	12
60-mm	5	3	9	1	0	1	0	0	0	0	0	0	19
2.75-in.	0	0	1	2	0	0	0	0	0	0	0	0	3
76-mm	0	0	0	0	0	0	0	0	0	0	0	0	0
81-mm	1	1	0	1	1	9	0	0	1	0	0	0	14
105-mm	0	0	0	0	0	0	0	0	0	0	0	0	0
4.2-in.	0	1	0	0	1	0	0	2	0	0	0	0	4
5.0-in.	0	0	0	0	0	0	0	0	0	0	0	0	0
152-mm	0	0	0	0	1	0	0	1	1	1	0	0	4
155-mm	2	0	0	0	2	0	3	0	2	2	4	0	15
Nonord	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	20	10	15	7	5	15	4	3	4	5	5	0	93
%classified	45.0	40.0	60.0	28.6	0.0	60.0	0.0	66.7	0.0	20.0	80.0		

Note: To convert inches to millimeters, multiply by 25.4.

Table 14
Classification Matrix without 90-Hz Data Aggregated by Ordnance Size

Classification	Ordnance Type		
	20-mm	57 to 81-mm	105 to 155-mm
20-mm	9	9	4
57- to 81-mm	9	38	1
105- to 155-mm	2	5	16
Total	20	52	21
% classified	45.0	73.1	76.2

relative to the calibration data, particular for data points with weak signals. This is as expected, given the greater noise level of the data acquired at that frequency. However, excluding some frequencies increases the potential for confusion between similar ordnance types.

Classification of All Detected Anomalies

The classifications in the preceding section involved only data points near actual targets; therefore, it demonstrates only the capability to separate different types of ordnance from each other given the presence of a target. However, in a realistic search scenario, real targets must be separated from clutter. To examine this aspect of classification with the GEM-3, data points near all objects declared by Geophex were extracted and the classification procedure repeated. An

Table 15
Classification Matrix without 90-Hz and 150-Hz Data

Classification	Ordnance Type												
	20-mm	57-mm	60-mm	2.75-in.	76-mm	81-mm	105-mm	4.2-in.	5.0-in.	152-mm	155-mm	FA	Total
20-mm	11	1	3	3	0	2	1	0	0	2	1	0	24
57-mm	1	4	2	0	0	3	0	0	0	0	0	0	10
60-mm	4	3	8	1	0	1	0	0	0	0	0	0	17
2.75-in.	0	0	1	1	0	0	0	0	0	0	0	0	2
76-mm	0	0	0	0	0	0	0	0	0	0	0	0	0
81-mm	2	1	1	1	1	9	0	0	0	0	0	0	15
105-mm	0	0	0	0	0	0	0	0	0	0	0	0	0
4.2-in.	0	0	0	0	1	0	0	3	0	1	0	0	5
5.0-in.	0	0	0	0	0	0	0	0	0	0	0	0	0
152-mm	0	0	0	0	1	0	0	0	1	0	0	0	2
155-mm	2	1	0	1	2	0	3	0	3	2	4	0	18
Nonord	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	20	10	15	7	5	15	4	3	4	5	5	0	93
%classified	55.0	40.0	53.3	14.3	0.0	60.0	0.0	100.0	0.0	0.0	80.0		

Note: To convert inches to millimeters, multiply by 25.4.

Table 16
Classification Matrix without 90-Hz and 150-Hz Data Aggregated by Ordnance Size

Classification	Ordnance Type		
	20-mm	57 to 81-mm	105 to 155-mm
20-mm	11	9	4
57- to 81-mm	7	37	0
105- to 155-mm	2	6	17
Total	20	52	21
% classified	55.0	71.2	81.0

ordnance/nonordnance threshold was specified to separate targets from clutter. The results of this classification using all frequencies at three different threshold levels are given in Tables 17 through 22. At the lowest threshold value used, 0.05, 23 of the 80 targets with calibration data were properly classified with 74 false alarms classified as ordnance. At a threshold of 0.1, 31 of the 80 targets are classified correctly with 155 false alarms classified as ordnance. At a threshold of 0.15, 38 of the 80 targets were correctly classified with 212 false alarms classified as ordnance. The biggest gains in the number of correctly classified targets as the threshold was raised were in the smaller-ordnance categories, especially the 20-mm projectiles where the number correct went from 1 at the lowest threshold to 8 at the highest.

Table 17
Classification Matrix with Threshold of 0.05

	Ordnance Type												
Classification	20-mm	57-mm	60-mm	2.75-in.	76-mm	81-mm	105-mm	4.2-in.	5.0-in.	152-mm	155-mm	FA	Total
20-mm	1	0	1	0	0	0	0	0	0	0	0	18	20
57-mm	0	4	2	0	0	2	0	0	0	0	0	5	13
60-mm	0	2	5	1	0	0	0	0	0	0	0	12	20
2.75in	1	0	0	0	1	0	0	0	0	0	0	12	14
76-mm	0	0	0	0	0	0	0	0	0	0	0	0	0
81-mm	0	1	1	0	1	8	0	0	0	0	0	13	24
105-mm	0	0	0	0	0	0	0	0	0	0	0	0	0
4.2-in.	0	0	0	0	0	0	0	3	0	0	0	7	10
5.0-in.	0	0	0	0	0	0	0	0	0	0	0	0	0
152-mm	0	0	0	0	1	0	0	0	1	0	0	5	7
155-mm	0	0	0	0	0	0	1	0	0	0	2	2	5
Nonord	17	3	6	6	2	4	3	0	3	5	3	450	502
Total	19	10	15	7	5	14	4	3	4	5	5	524	615
%classified	5.3	40.0	33.3	0.0	0.0	57.1	0.0	100.0	0.0	0.0	40.0		

Note: To convert inches to millimeters, multiply by 25.4.

Table 18
Classification Matrix Aggregated by Ordnance Size with Threshold of 0.05

	Ordnance Type			
Classification	**20-mm**	**57 to 81-mm**	**105 to 155-mm**	**False Alarm**
20-mm	1	1	0	18
57- to 81-mm	1	28	0	42
105- to 155-mm	0	1	7	14
Nonordnance	17	21	14	450
Total	19	51	21	524
% classified	5.3	54.9	33.3	85.9

Table 19
Classification Matrix with Threshold of 0.1

Classification	20-mm	57-mm	60-mm	2.75-in.	76-mm	81-mm	105-mm	4.2-in.	5.0-in.	152-mm	155-mm	FA	Total
	Ordnance Type												
20-mm	3	0	1	0	0	0	1	0	0	0	0	60	65
57-mm	0	4	2	0	0	2	0	0	0	0	0	13	21
60-mm	0	3	7	1	0	0	0	0	1	0	0	18	30
2.75in	2	0	0	1	1	0	0	0	0	0	0	20	24
76-mm	0	0	0	0	0	0	0	0	0	0	0	0	0
81-mm	0	2	1	0	1	10	0	0	0	0	0	17	31
105-mm	0	0	0	0	0	0	0	0	0	0	0	0	0
4.2-in.	0	0	0	1	0	0	0	3	0	1	0	11	16
5.0-in.	0	0	0	0	0	0	0	0	0	0	0	0	0
152-mm	0	0	0	0	1	0	0	0	1	0	0	6	8
155-mm	0	0	0	0	0	0	2	0	0	2	3	10	17
Nonord	14	1	4	4	2	2	1	0	2	2	2	369	403
Total	19	10	15	7	5	14	4	3	4	5	5	524	615
%classified	15.8	40.0	46.7	14.3	0.0	71.4	0.0	100.0	0.0	0.0	60.0		

Note: To convert inches to millimeters, multiply by 25.4.

Table 20
Classification Matrix Aggregated by Ordnance Size with Threshold of 0.1

Classification	Ordnance Type			
	20-mm	57- to 81-mm	105- to 155-mm	False Alarm
20-mm	3	1	1	60
57- to 81-mm	2	35	1	68
105- to 155-mm	0	2	12	27
Nonordnance	14	13	7	369
Total	19	51	21	524
% classified	15.8	68.6	57.1	70.4

Table 21
Classification Matrix with Threshold of 0.15

Classification	Ordnance Type 20-mm	57-mm	60-mm	2.75-in.	76-mm	81-mm	105-mm	4.2-in.	5.0-in.	152-mm	155-mm	FA	Total
20-mm	8	0	1	0	0	0	1	0	0	0	0	90	100
57-mm	1	4	2	0	0	2	0	0	0	0	0	13	22
60-mm	1	3	8	1	0	1	0	0	1	0	0	21	36
2.75in	2	1	0	2	1	1	0	0	0	0	0	24	31
76-mm	0	0	0	0	0	0	0	0	0	0	0	0	0
81-mm	0	2	1	0	1	10	0	0	0	1	0	20	35
105-mm	0	0	0	0	0	0	0	0	0	0	0	0	0
4.2-in.	0	0	1	1	0	0	0	3	0	1	0	13	19
5.0-in.	0	0	0	0	0	0	0	0	0	0	0	0	0
152-mm	0	0	0	0	1	0	0	0	1	0	0	7	9
155-mm	0	0	0	0	1	0	2	0	1	2	3	24	33
Nonord	7	0	2	3	1	0	1	0	1	1	2	312	330
Total	19	10	15	7	5	14	4	3	4	5	5	524	615
%classified	42.1	40.0	53.3	28.6	0.0	71.4	0.0	100.0	0.0	0.0	60.0		

Note: To convert inches to millimeters, multiply by 25.4.

Table 22
Classification Matrix Aggregated by Ordnance Size with Threshold of 0.15

Classification	Ordnance Type			
	20-mm	57- to 81-mm	105- to 155-mm	False Alarm
20-mm	8	1	1	90
57- to 81-mm	4	40	2	78
105- to 155-mm	0	4	13	44
Nonordnance	7	6	5	312
Total	19	51	21	524
% classified	42.1	78.4	61.9	59.5

4 Summary and Recommendations

The GEM-3 data collected as part of the Advanced UXO Detection/ Discrimination Technology Demonstration at JPG have been analyzed to determine the UXO classification capabilities of the GEM-3. Although the GEM-3 performed well in detecting anomalies at the site, the classification results achieved by Geophex at JPG were somewhat disappointing, especially for the larger ordnance types. The results presented here indicate that, while sensor constraints and test parameters contributed to some misclassifications, the results could have been significantly better than they were.

Sensor coverage of the target areas at a spacing of 0.5 m appears to be adequate. Several data points were acquired near each target. Tighter spacing of measurements would likely improve performance against very small targets like the 20-mm projectiles. Good signatures for these targets were obtained only when the sensor was nearly centered on the target. It is also possible that the density of measurements near some targets was not sufficient to support the classification scheme used by Geophex.

The data points acquired near each target were individually compared with calibration data for the target's ordnance type so that the variability of the data could be examined. Even allowing for differences that result from the differing orientation of the target relative to the sensor, the comparisons showed a high degree of variability among the data points near many targets. While at least one point near almost every target closely matched the signature of the correct ordnance type, there were other points near most targets that did not match the signature for any ordnance favorably. The degree of uncertainty in a given measurement makes classification unreliable, especially for small or deep targets. This report also presents statistical analysis of data of fixed targets over a period of time acquired by ERDC personnel with the GEM-3 in a preliminary attempt to determine the precision of the instrument.

The effect of the size and depth of the targets on classification was examined. The smallest ordnance in the demonstration, 20-mm projectiles, was the only ordnance that was difficult to detect regardless of depth. All the other ordnance types produced strong responses in the sensor at shallower depths. However, the deepest targets of several ordnance types resulted in signal strength on the order of the sensor fluctuations, making reliable classification unlikely.

To quantify the classification capabilities of the GEM-3, the targets were classified using a template-matching algorithm that compared the data point having the greatest magnitude near each object to calibration signatures for the different ordnance types and assigned the object to the closest matching ordnance type. This procedure resulted in an exact classification match for nearly half of the targets for more than two-thirds of the medium and large targets. This classification, based on a single selected data point for each detected object, is intended to serve as a baseline. In theory, more sophisticated algorithms that use all of the available data points near each object should perform better. However, because of the variability among data points near the same target, this may not be the case.

The results presented here indicate that the GEM-3, has outstanding potential to detect and classify UXO. While sensor limitations and test parameters contributed to some misclassification of objects from the JPG demonstration, the primary problem identified in this analysis is the variability in sensor response throughout the demonstration. The data taken at JPG and ERDC indicate that both drift and abrupt shifts in the level of sensor response occurred in the GEM-3 system. A careful look into the extent and cause of these sensor variations is necessary to determine if they can be removed or characterized such that they may be minimized and not affect the results of the data analysis.

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Appendix A Area Coverage Maps with Histograms

In an effort to better understand what the data look like, it was essential to view the data in an easily understandable way. To visualize the data, it was necessary to create a separate map for each frequency measured for both the in-phase and quadrature components. The pixel, representing that coordinate, is assigned a color based on a scale generated to cover the dynamic range of the data for all of the frequencies for a given component. Using the histogram that was produced earlier, the background values may be removed using the slider bars on the histogram panel, thus leaving only the "target" items visible on the plot. This can be done for either the entire area or a smaller section of the data.

Background values may be "removed" from the plots by selecting a threshold range for each frequency for both in-phase and quadrature; this allows the user to interactively select values to define background from the histogram by viewing the area map with those values removed or blacked out. The result of this process is a significantly enhanced view of the anomalies in the area map. The user may step through the different frequencies interactively removing the background from the in-phase and quadrature measurements to visually locate the anomalies in the area.

Once the plots have been rendered, the user may click on a suspected target and get the GPS coordinates and the full spectra of frequencies for both in-phase and quadrature components.

An investigation into the variation of the measurements throughout each site produces some interesting results. Figures A1-A42 show renderings of the values that were found in all the areas for both the quadrature and the in-phase measurements. These mappings were normalized globally so that the scale is the same frequency for a given area. In-phase and quadrature values are scaled to use the color map underneath the histograms at the bottom of each screen. The histograms at the bottom of the page are plotted on a vertical log scale in order to increase the vertical dynamic range that is displayed. Consequently, this will enhance the anomalies, which have fewer points and are well away from the background peak(s).

These histograms show the distribution of all the measurements made of that site for a given frequency. An ideal site would have a large peak, which would represent the background value, and other much smaller peaks that would be indicative of targets. The less homogeneous the background, the broader the background peak should be.

Since the background peak was not sharply defined, a method to determine a more accurate background for the target was developed. The technique was to select an area around the anomaly but exclude the local area about the anomaly, and calculate a histogram for that area. It was expected that these areas would have a single well-defined peak. The location of the peak would be a good representation of the background value in that area. This was not always true and the exceptions to this are discussed further in the analysis.

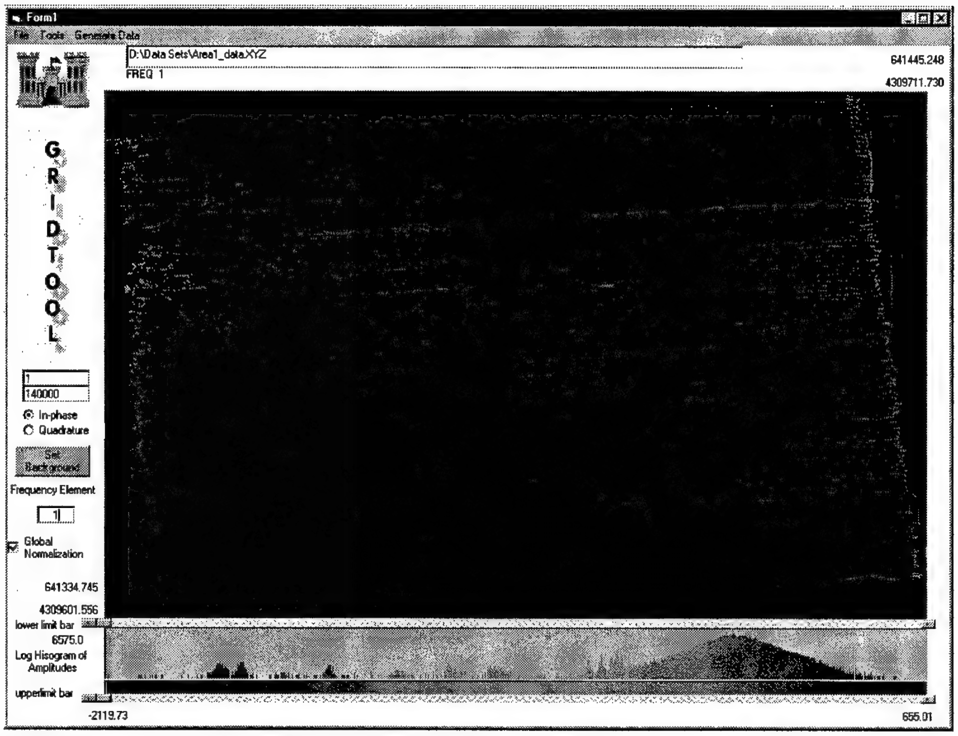


Figure A1. Area 1 in-phase coverage map for 90 Hz

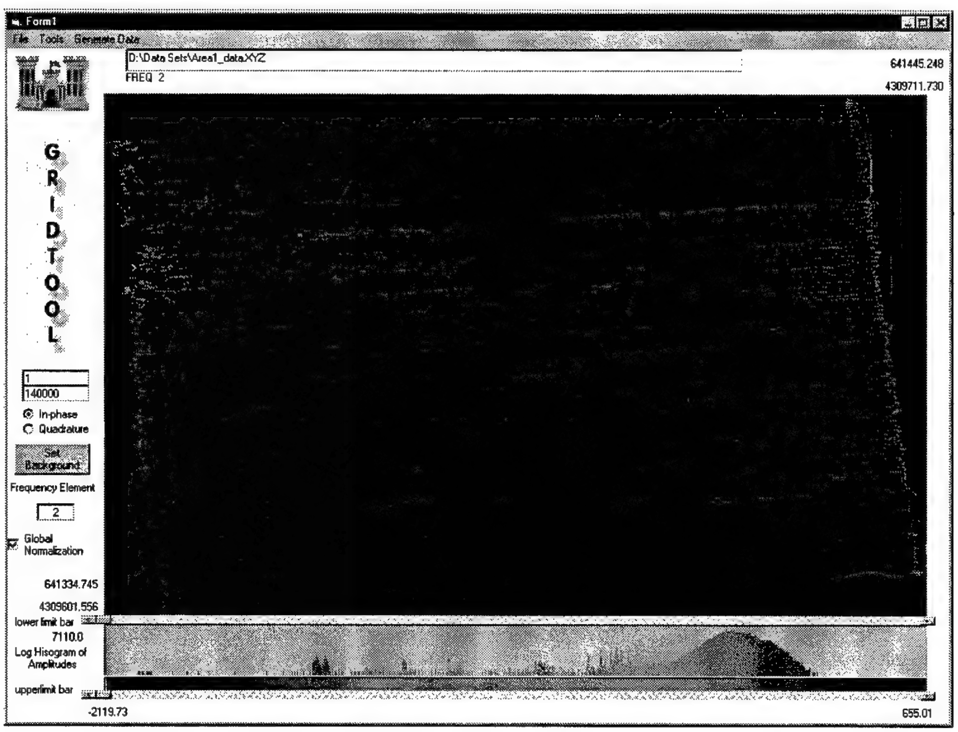


Figure A2. Area 1 in-phase coverage map for 150 Hz

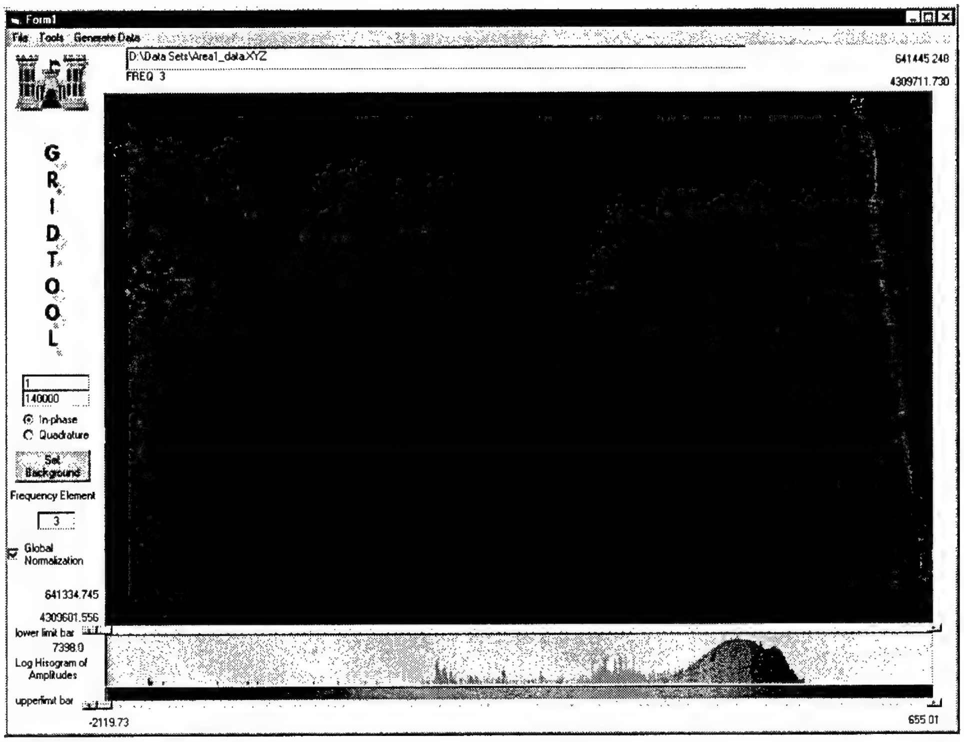


Figure A3. Area 1 in-phase coverage map for 330 Hz

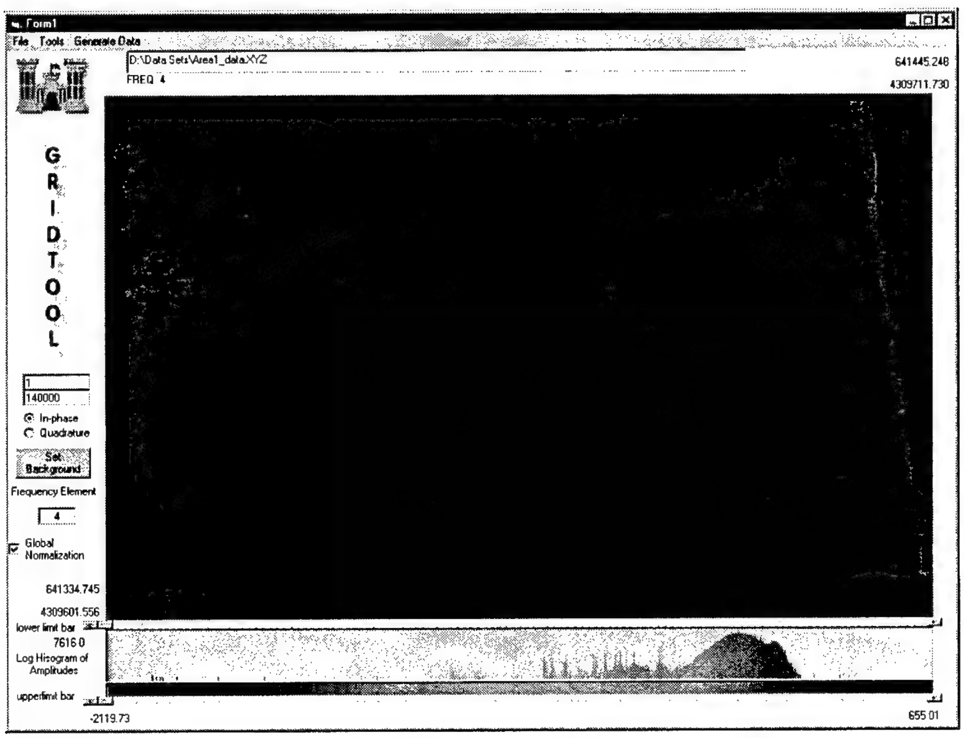


Figure A4. Area 1 in-phase coverage map for 930 Hz

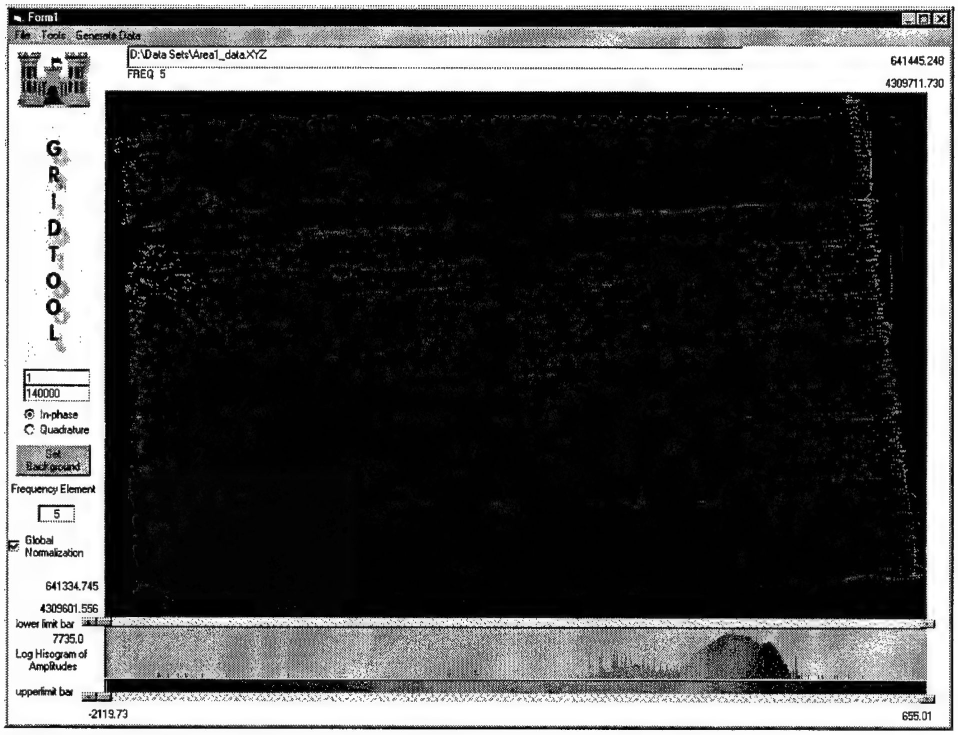


Figure A5. Area 1 in-phase coverage map for 2,790 Hz

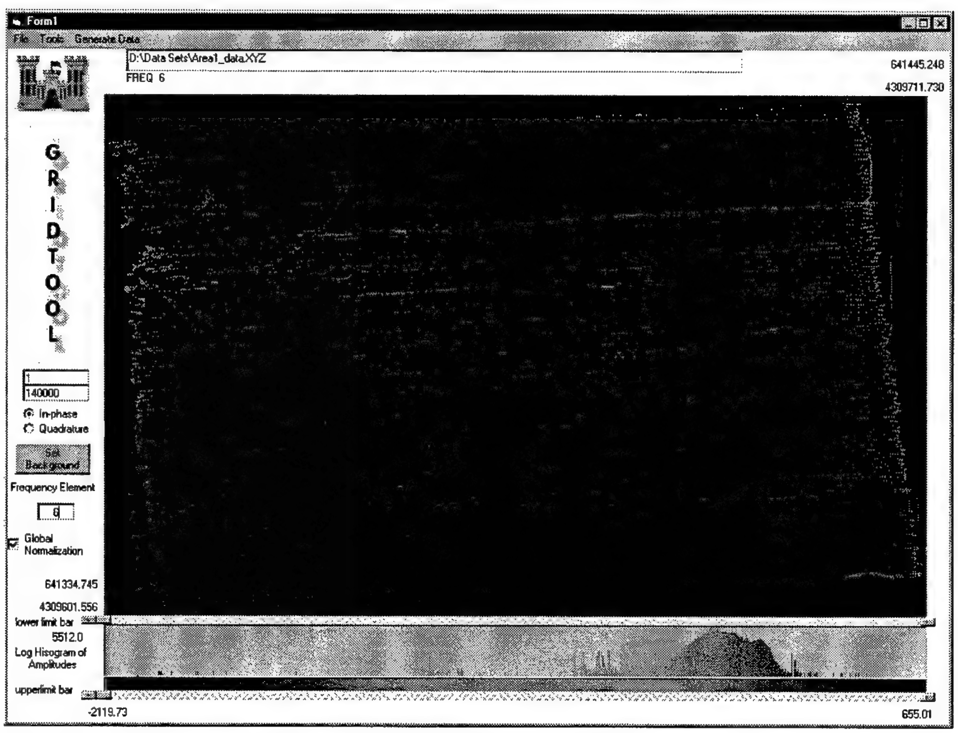


Figure A6. Area 1 in-phase coverage map for 8,190 Hz

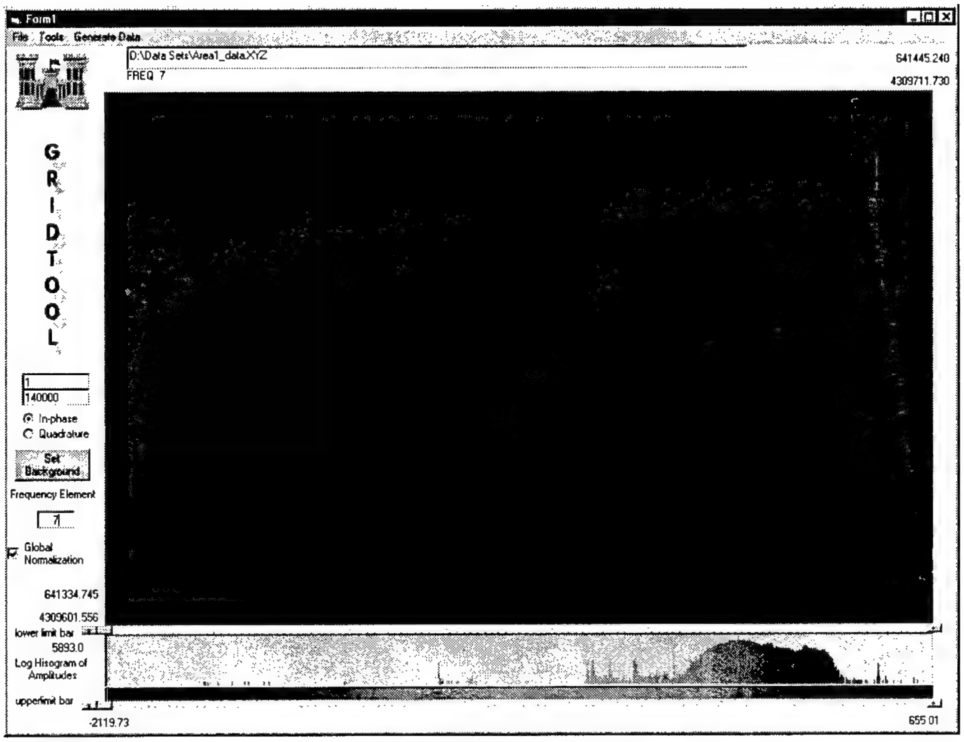


Figure A7. Area 1 in-phase coverage map for 20,010 Hz

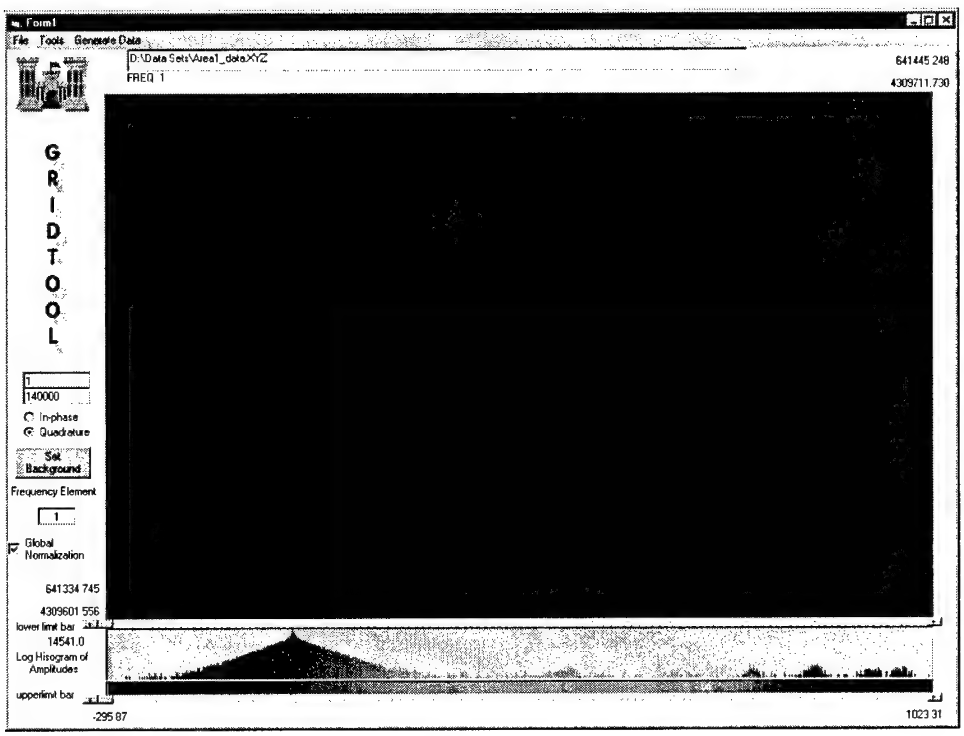


Figure A8. Area 1 quadrature coverage map for 90 Hz

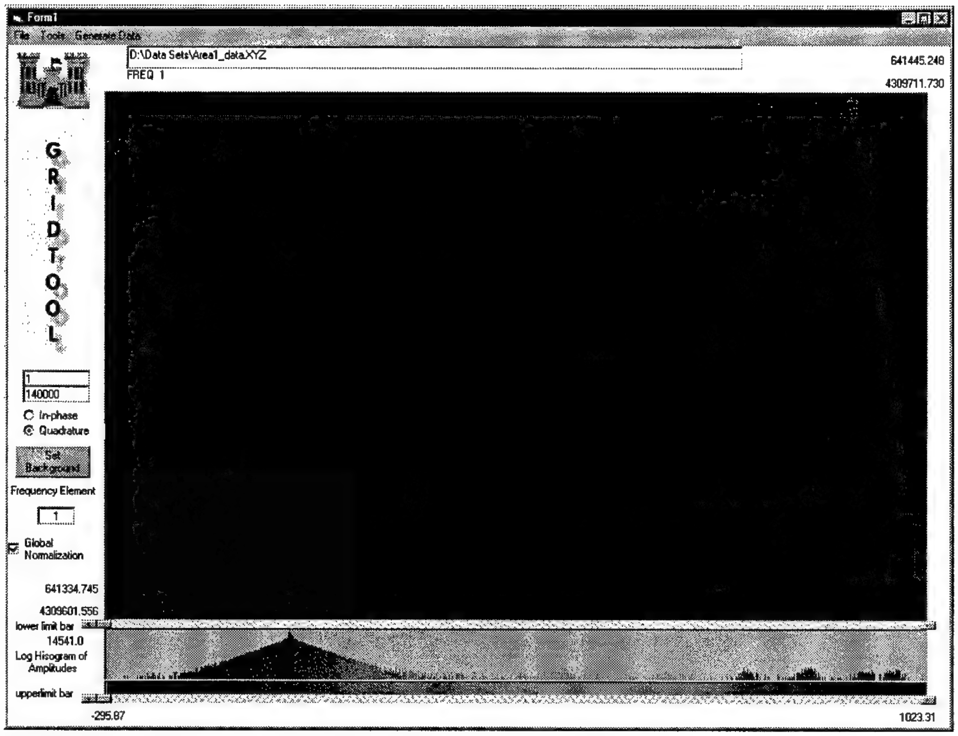


Figure A9. Area 1 quadrature coverage map for 150 Hz

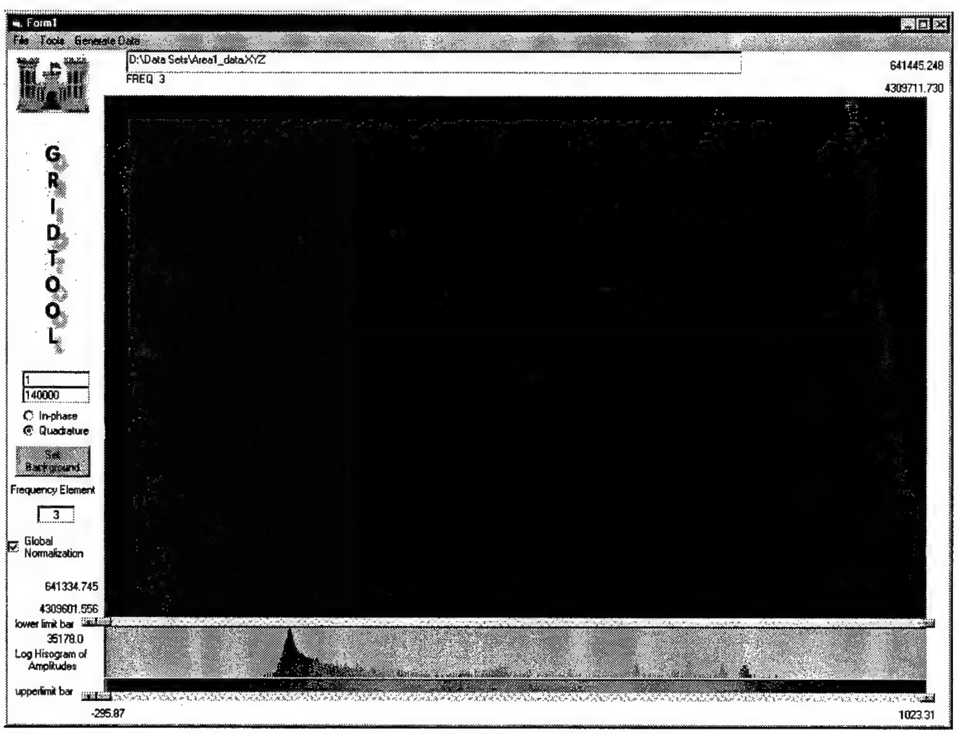


Figure A10. Area 1 quadrature coverage map for 330 Hz

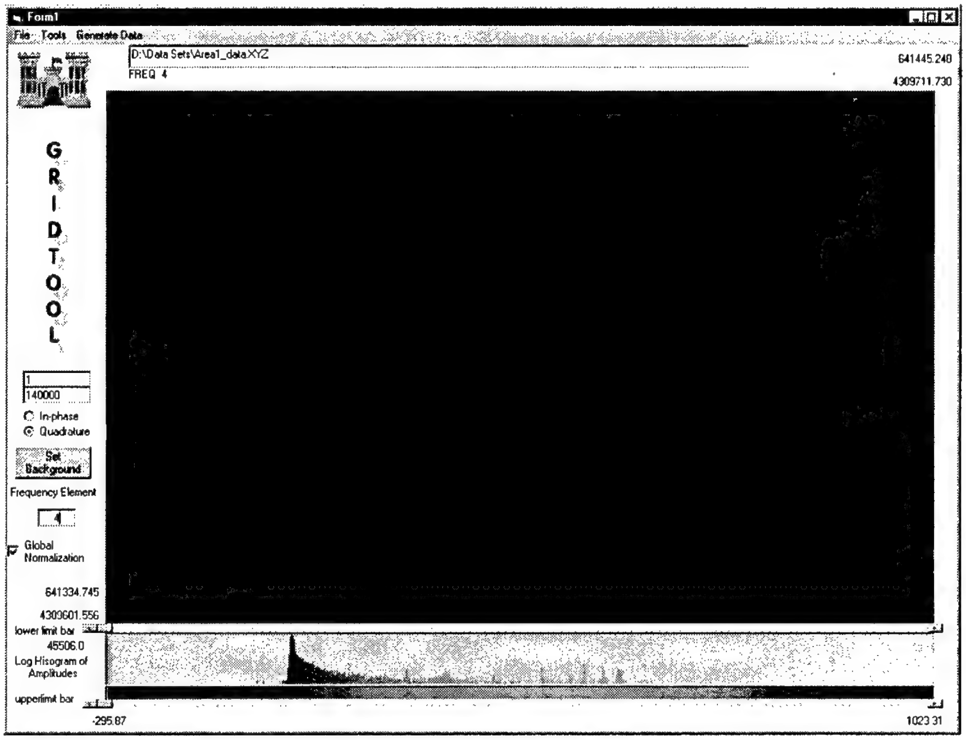


Figure A11. Area 1 quadrature coverage map for 930 Hz

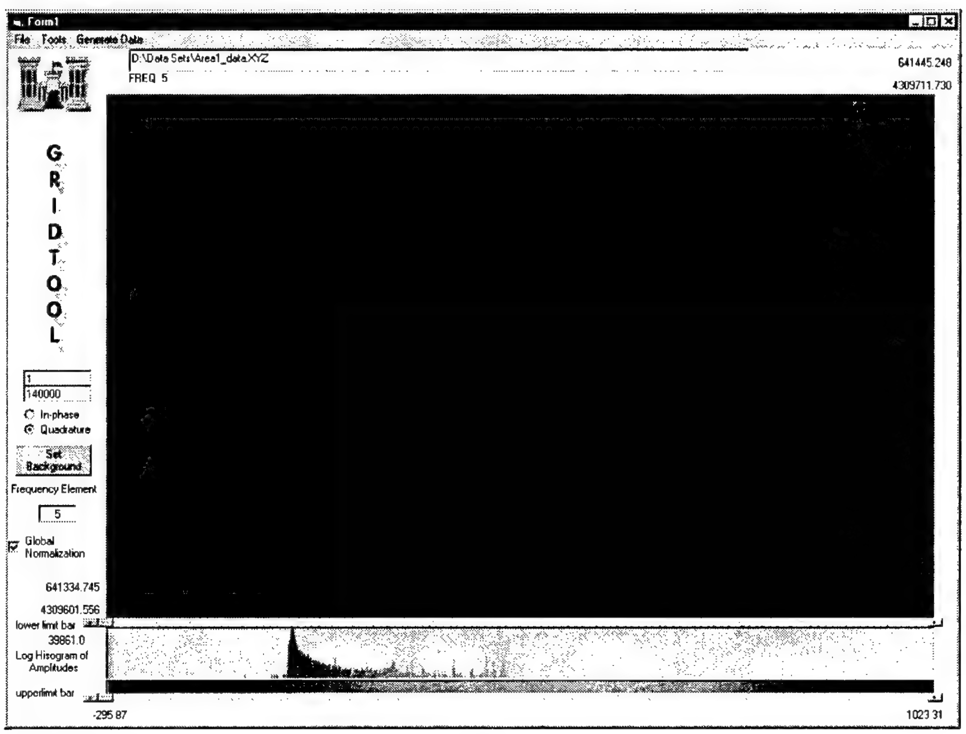


Figure A12. Area 1 quadrature coverage map for 2,790 Hz

Figure A13. Area 1 quadrature coverage map for 8,190 Hz

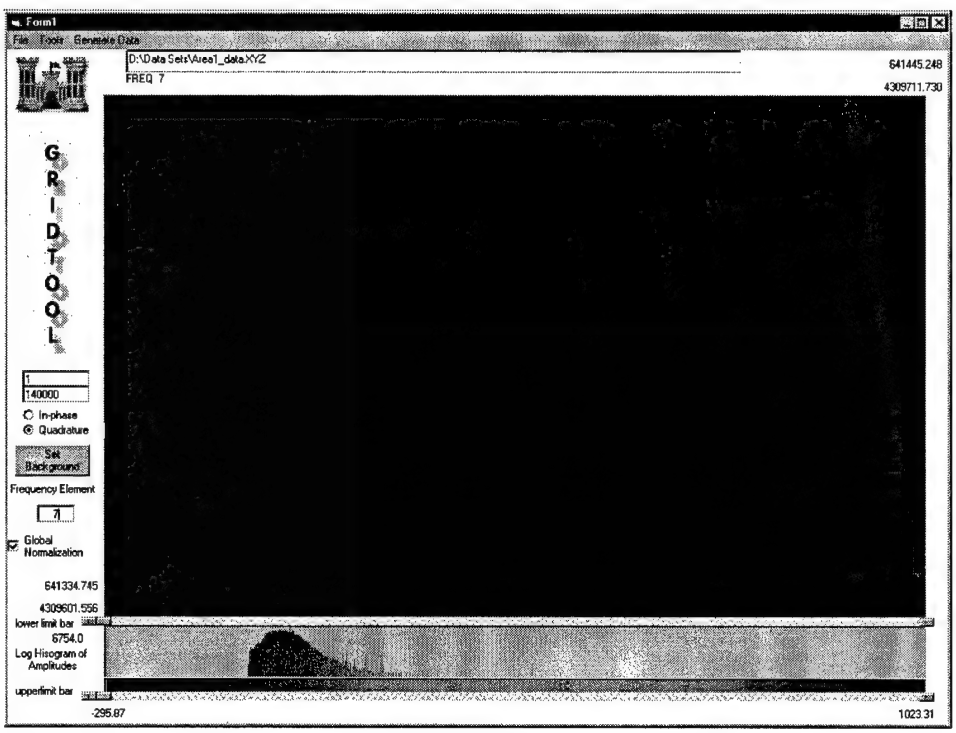


Figure A14. Area 1 quadrature coverage map for 20,010 Hz

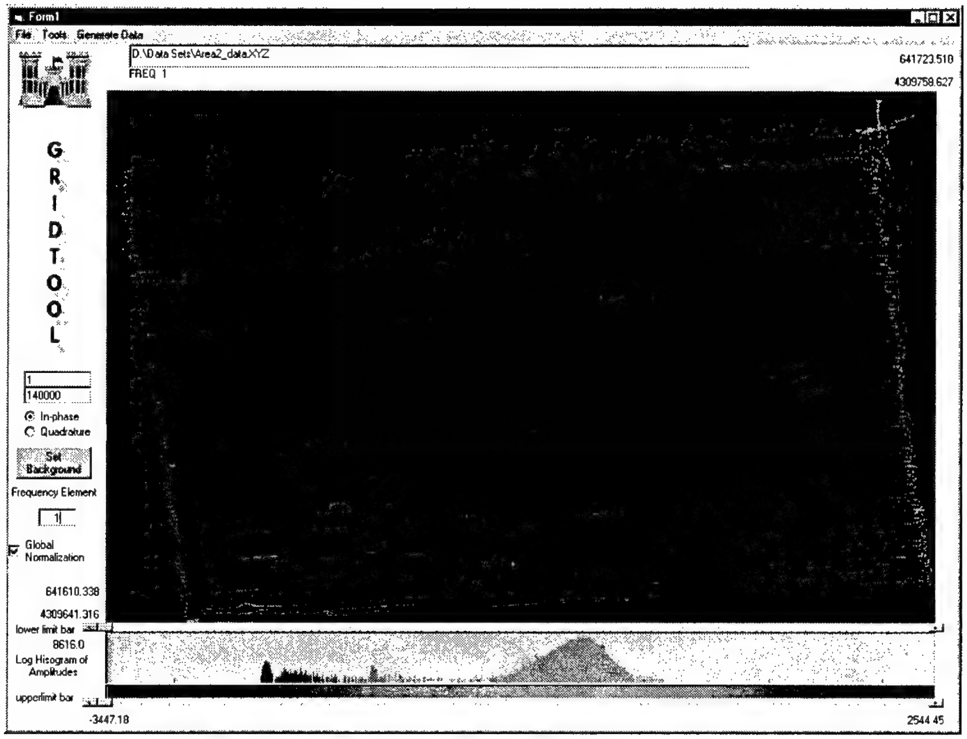


Figure A15. Area 2 in-phase coverage map for 90 Hz

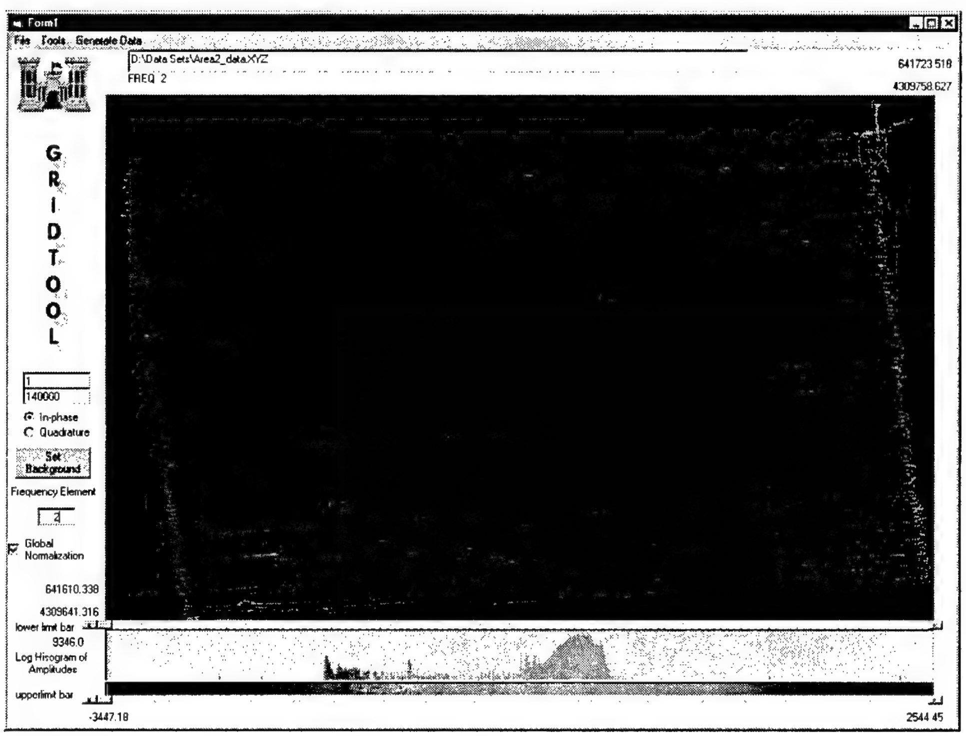


Figure A16. Area 2 in-phase coverage map for 150 Hz

Figure A17. Area 2 in-phase coverage map for 330 Hz

Figure A18. Area 2 in-phase coverage map for 930 Hz

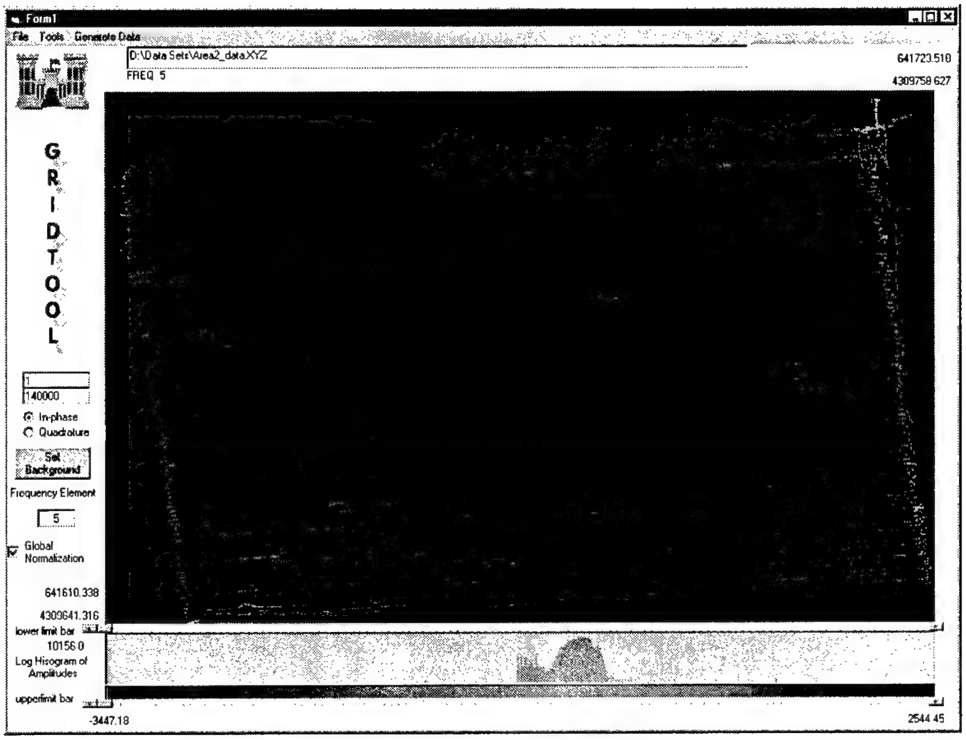


Figure A19. Area 2 in-phase coverage map for 2,790 Hz

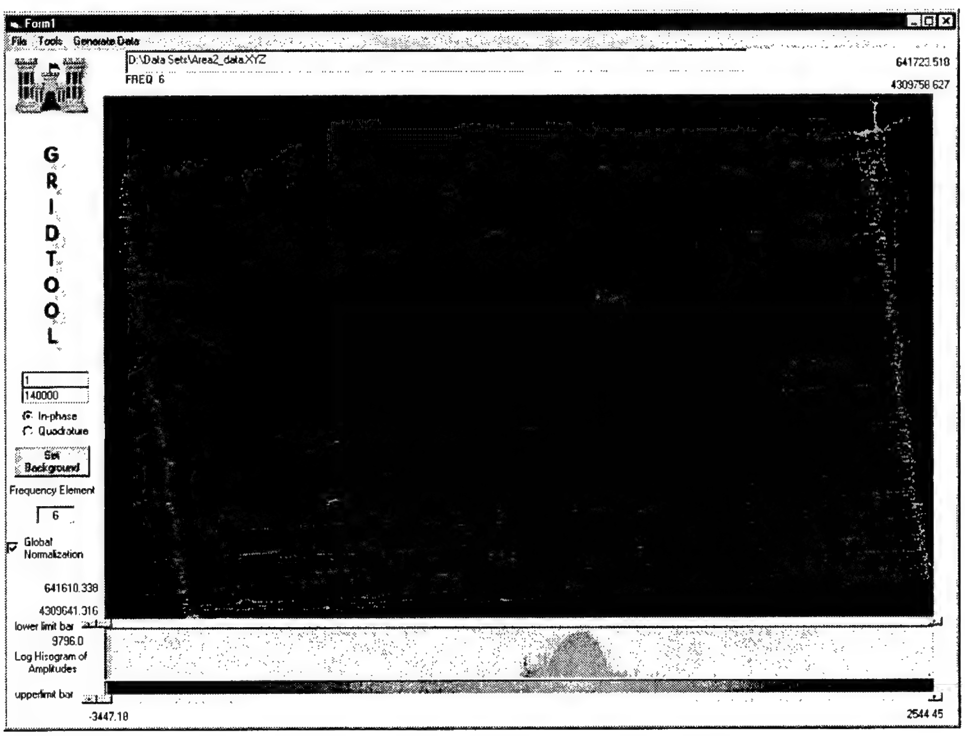


Figure A20. Area 2 in-phase coverage map for 8,190 Hz

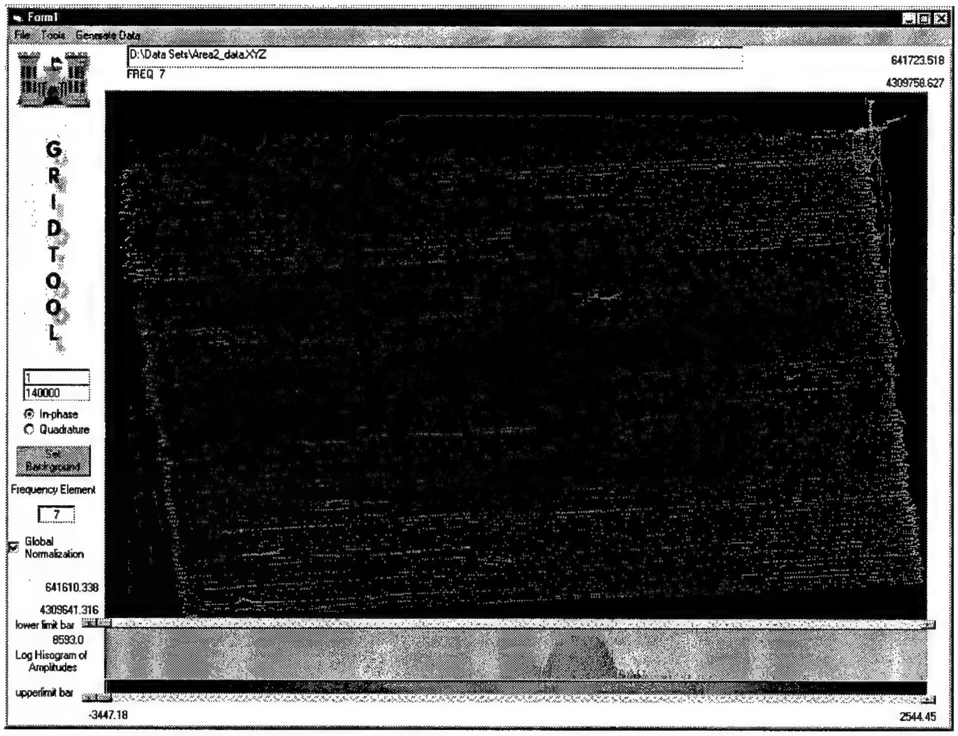


Figure A21. Area 2 in-phase coverage map for 20,010 Hz

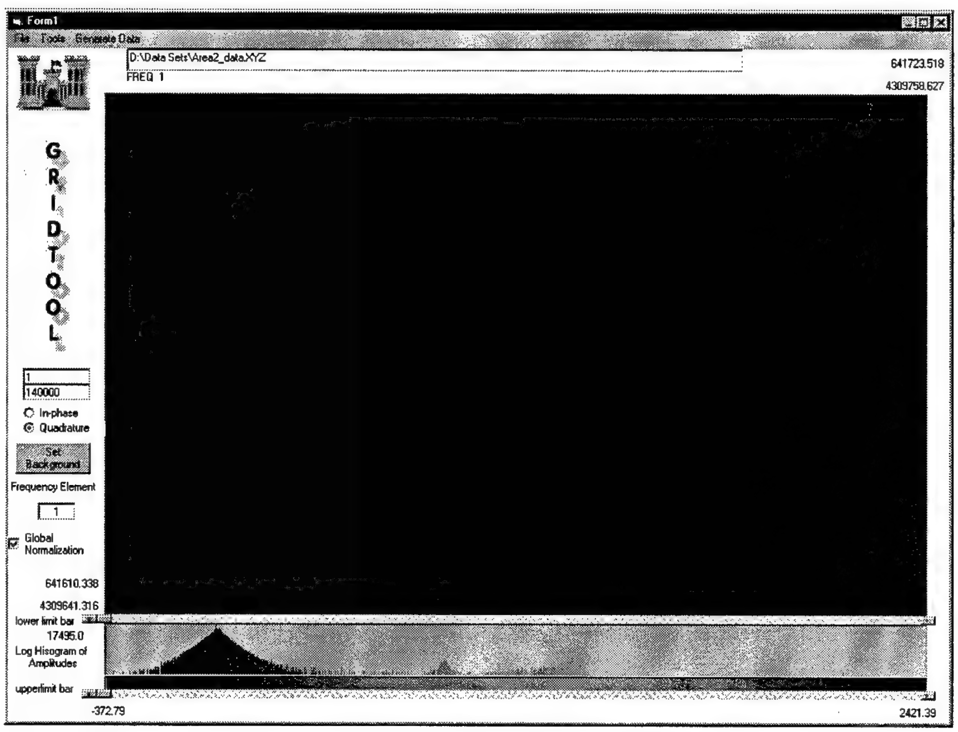


Figure A22. Area 2 quadrature coverage map for 90 Hz

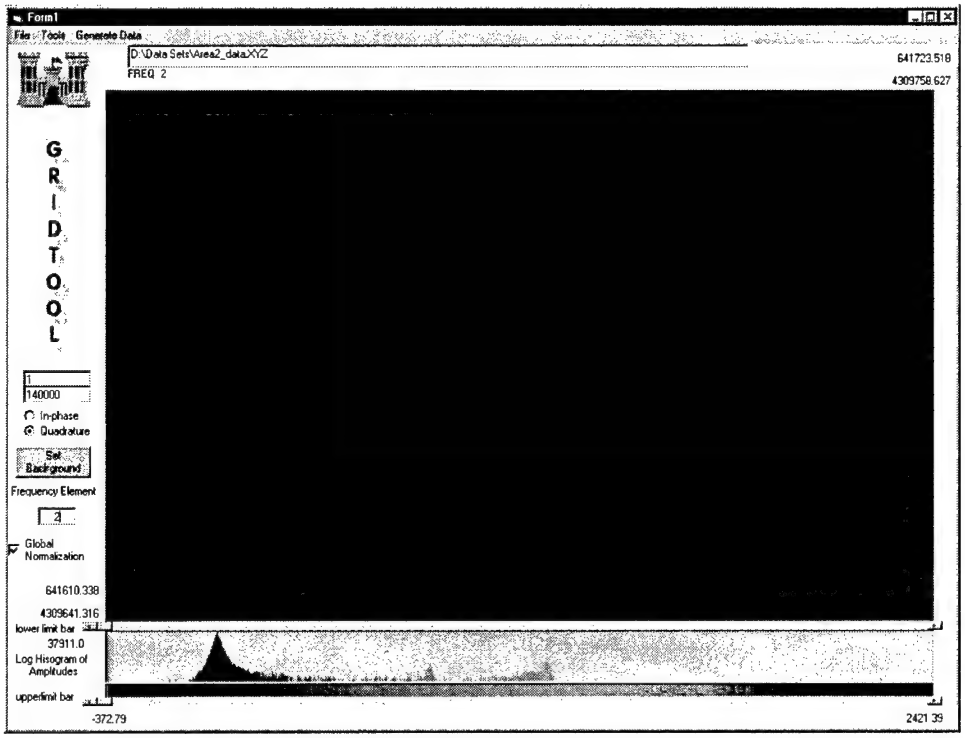


Figure A23. Area 2 quadrature coverage map for 150 Hz

Figure A24. Area 2 quadrature coverage map for 330 Hz

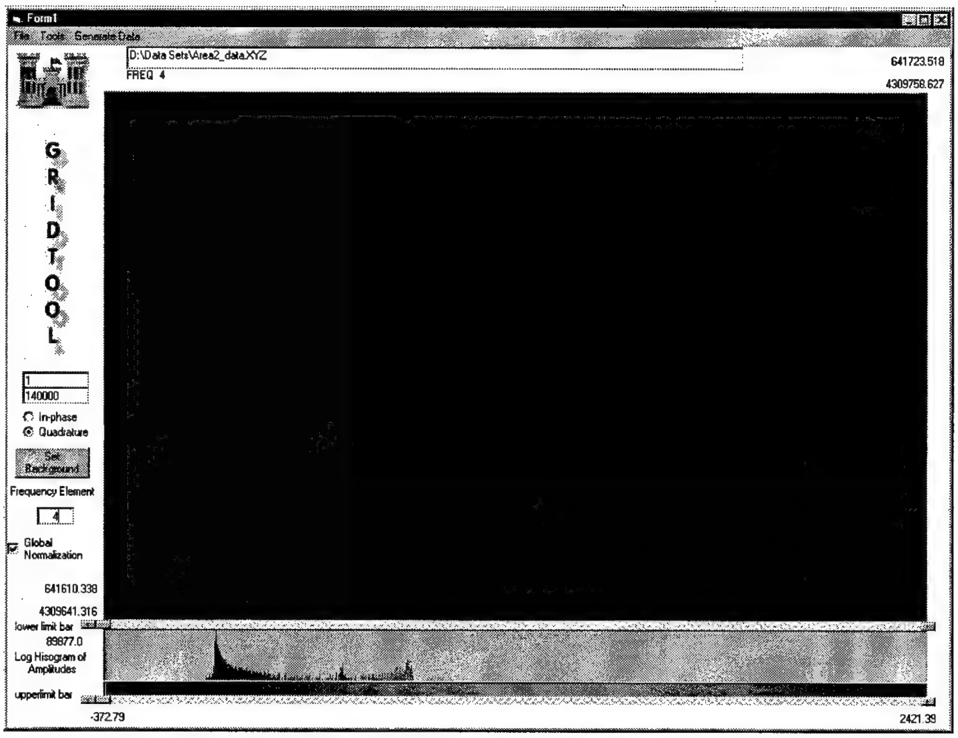


Figure A25. Area 2 quadrature coverage map for 930 Hz

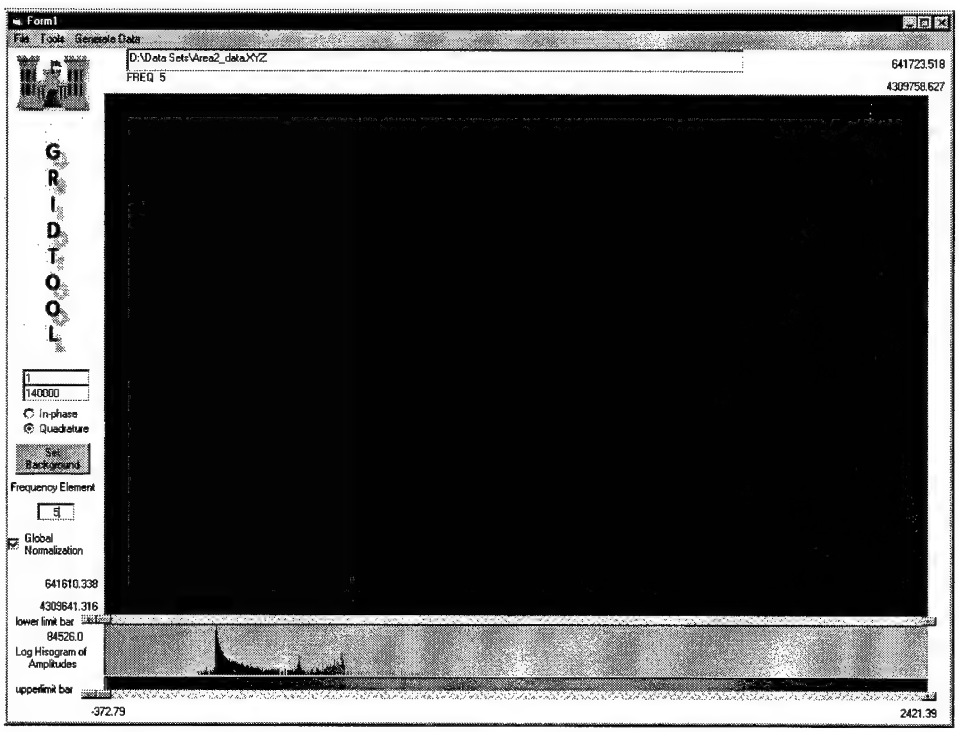


Figure A26. Area 2 quadrature coverage map for 2,790 Hz

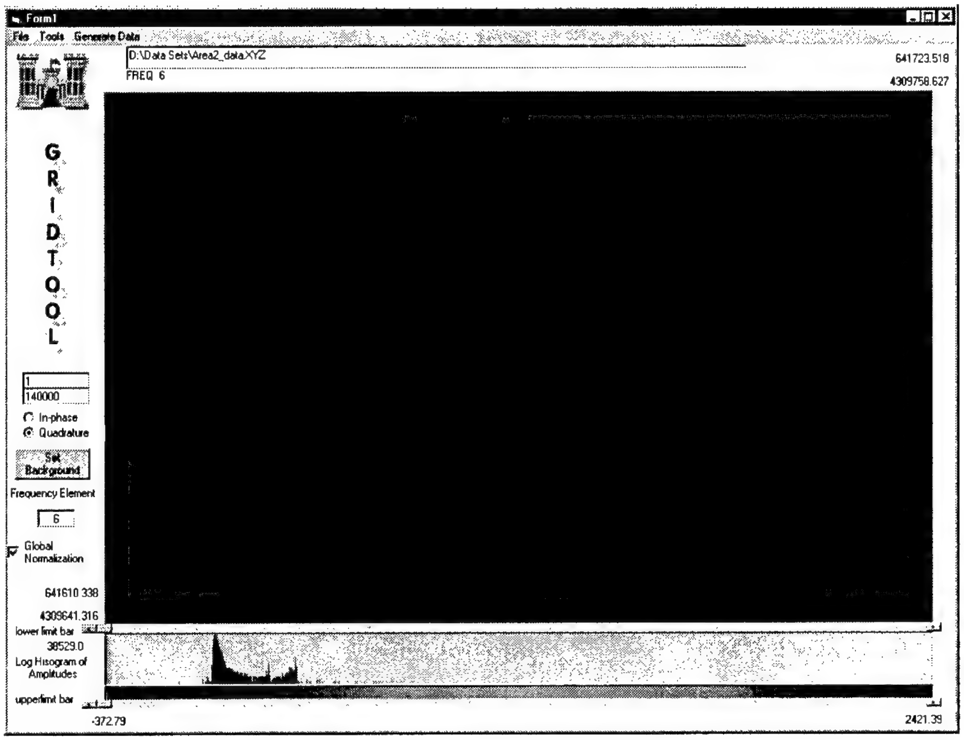


Figure A27. Area 2 quadrature coverage map for 8,190 Hz

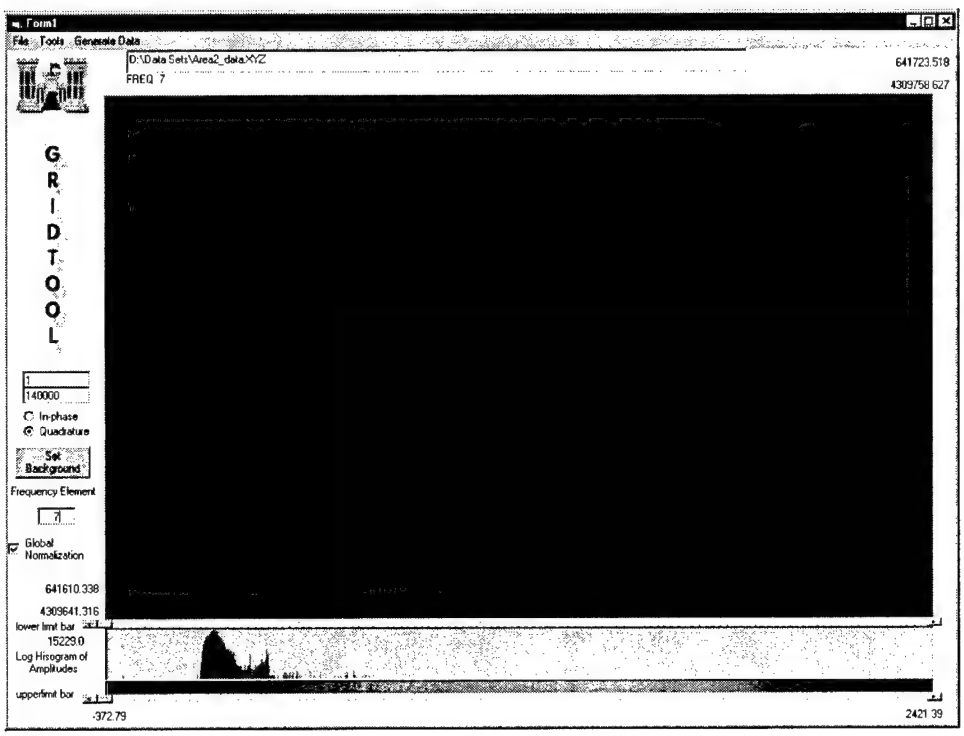


Figure A28. Area 2 quadrature coverage map for 20,010 Hz

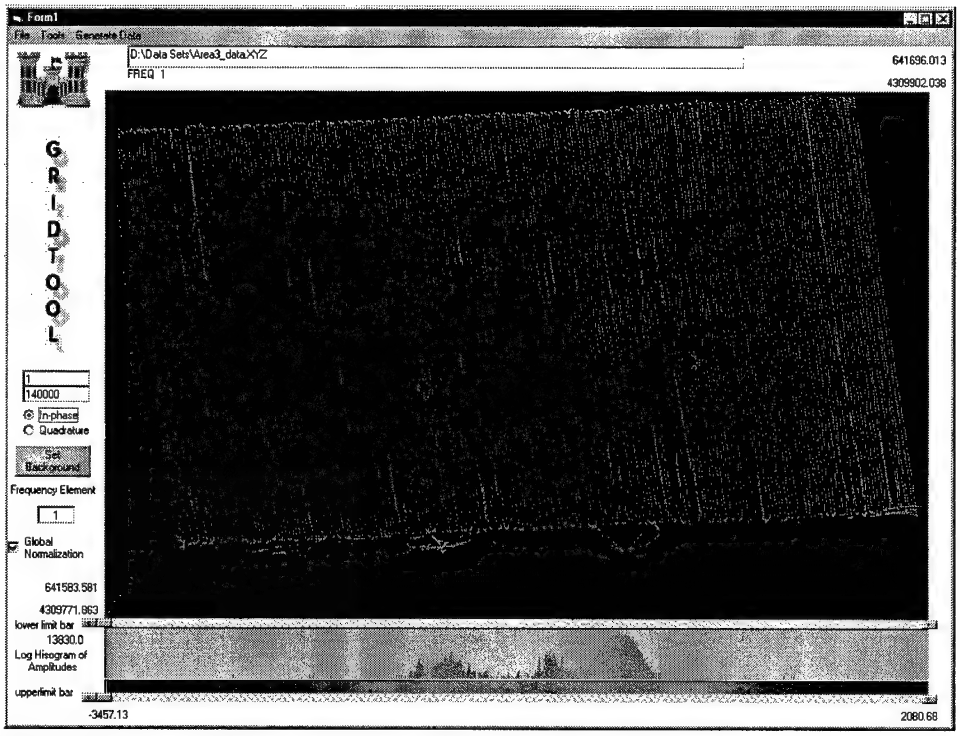


Figure A29. Area 3 in-phase coverage map for 90 Hz

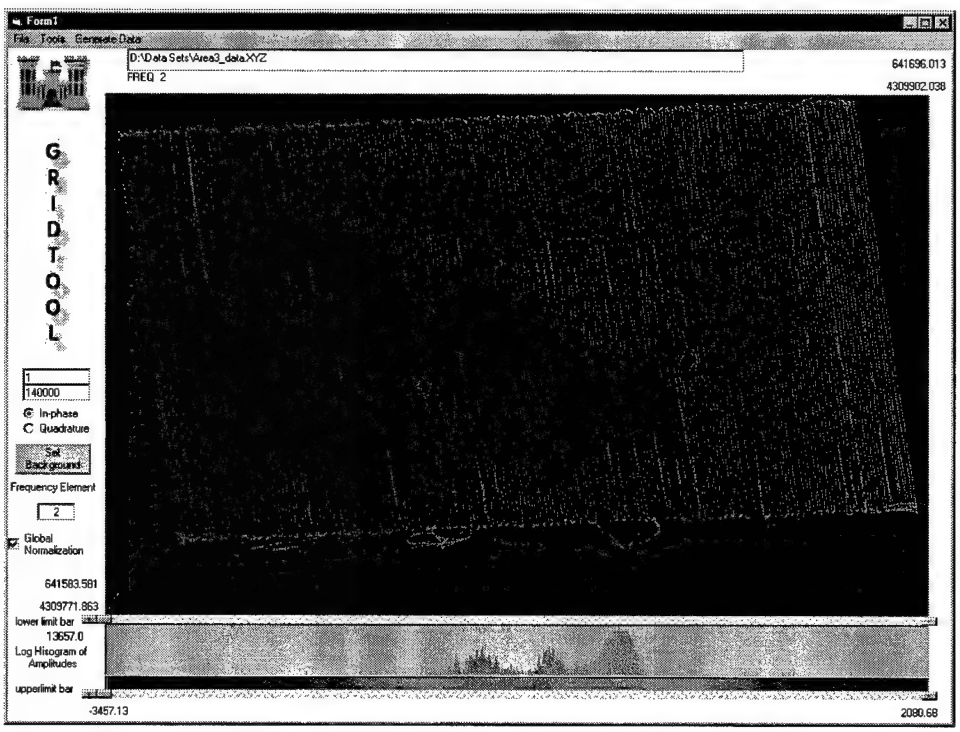


Figure A30. Area 3 in-phase coverage map for 150 Hz

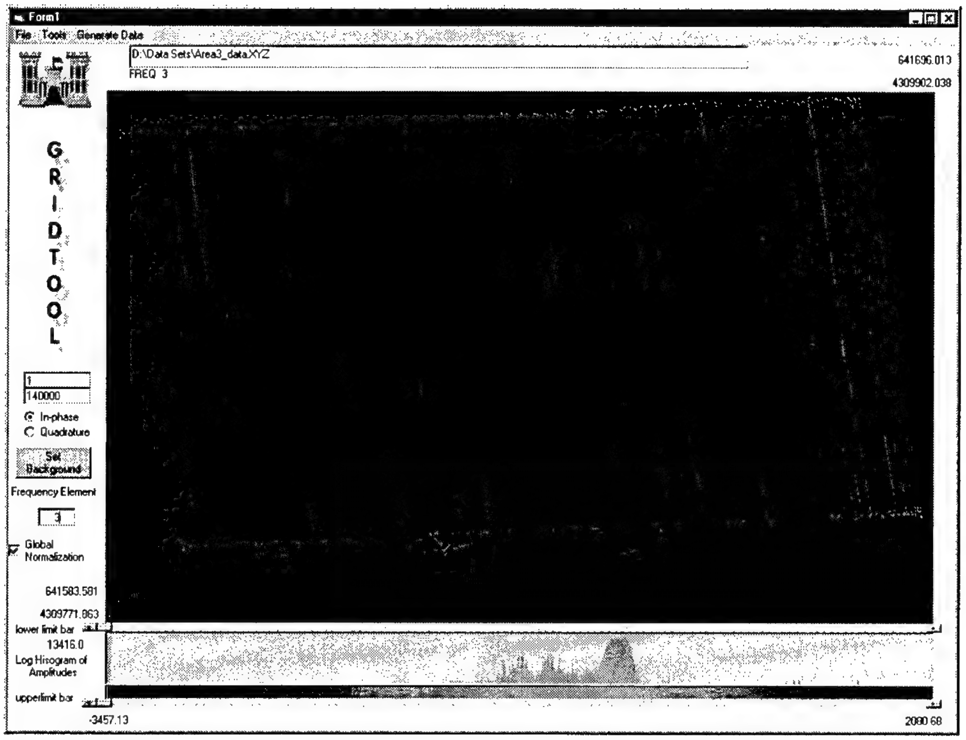


Figure A31. Area 3 in-phase coverage map for 330 Hz

Figure A32. Area 3 in-phase coverage map for 930 Hz

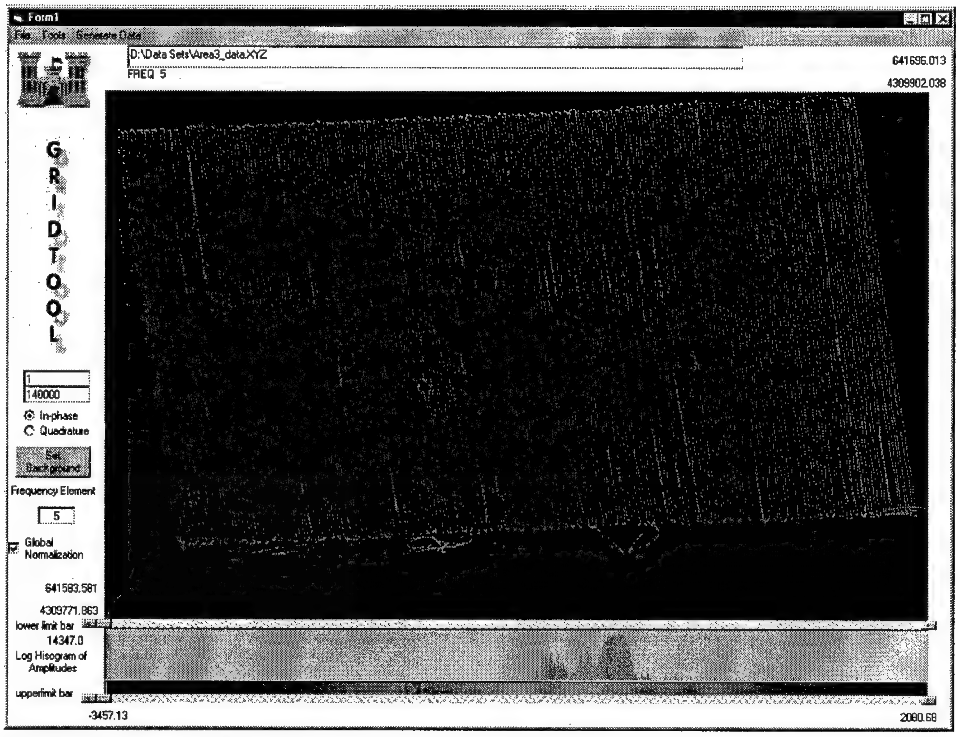


Figure A33. Area 3 in-phase coverage map for 2,790 Hz

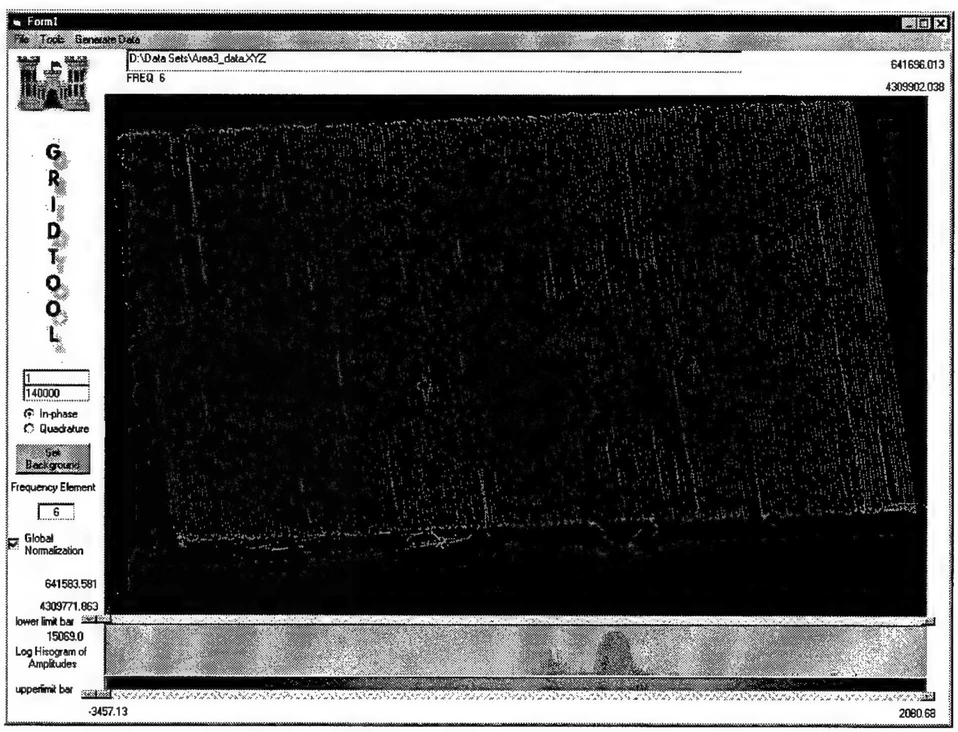


Figure A34. Area 3 in-phase coverage map for 8,190 Hz

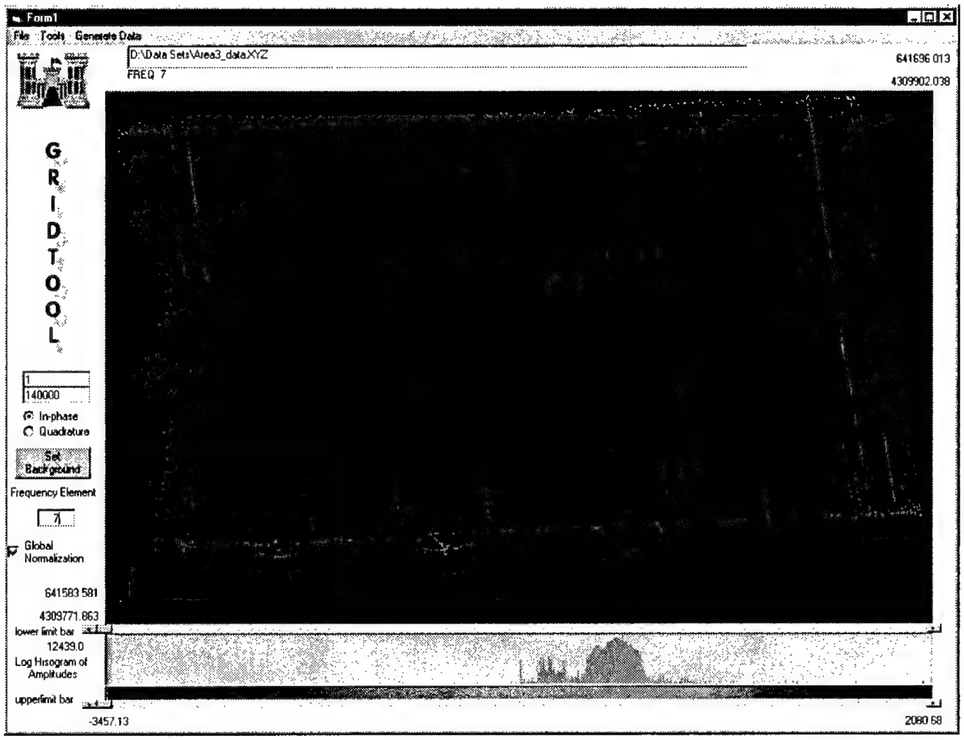


Figure A35. Area 3 in-phase coverage map for 20,010 Hz

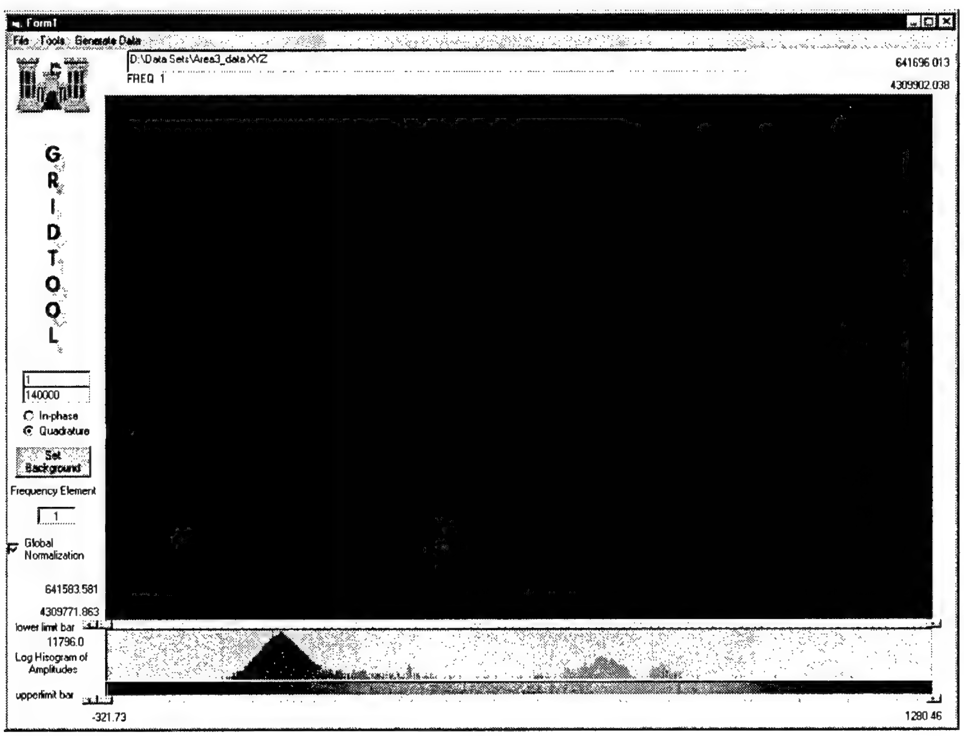


Figure A36. Area 3 quadrature coverage map for 90 Hz

Figure A37. Area 3 quadrature coverage map for 150 Hz

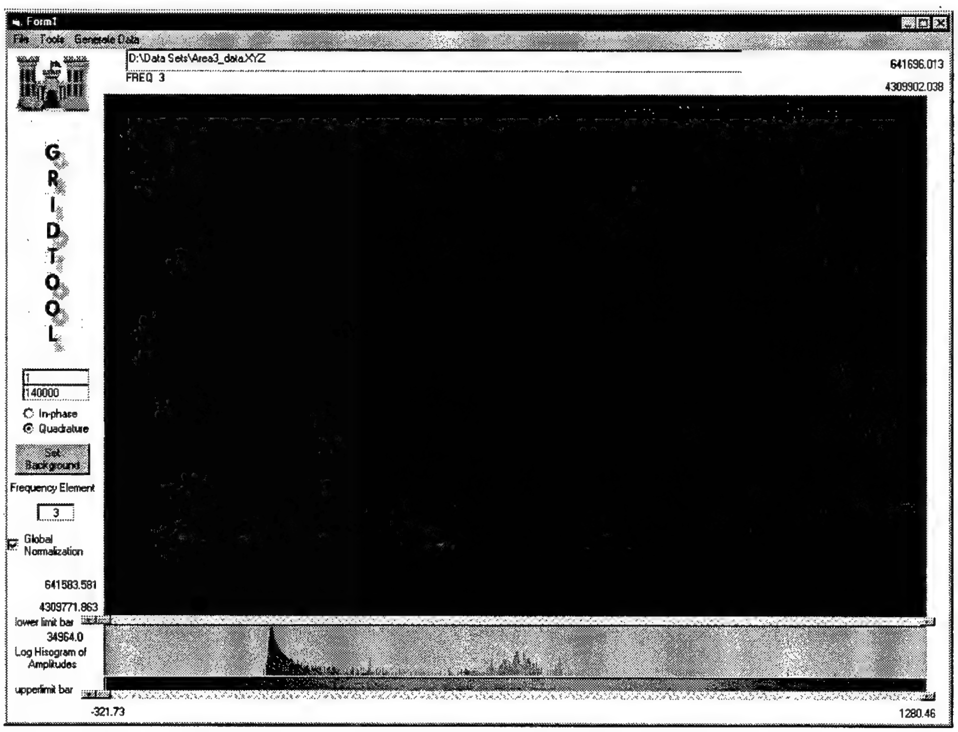


Figure A38. Area 3 quadrature coverage map for 330 Hz

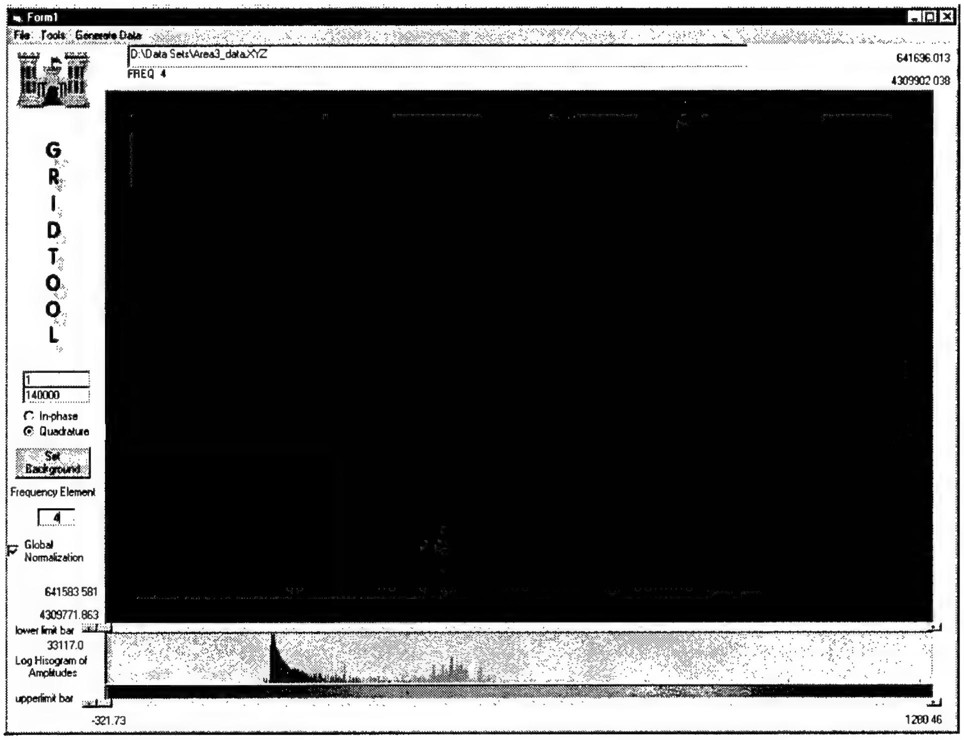


Figure A39. Area 3 quadrature coverage map for 930 Hz

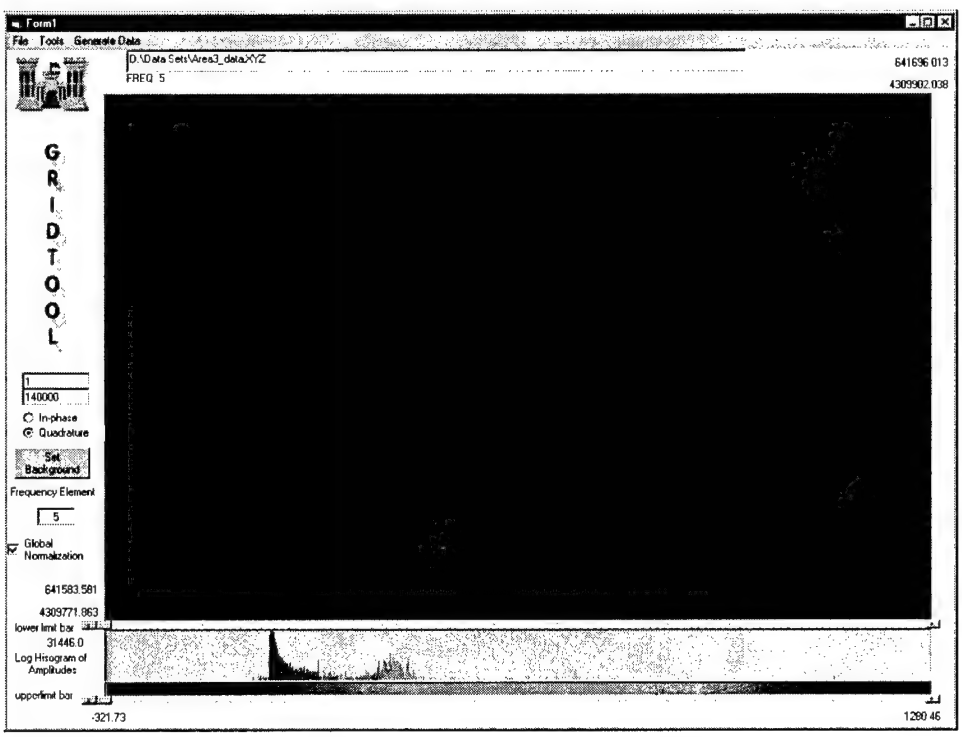


Figure A40. Area 3 quadrature coverage map for 2,790 Hz

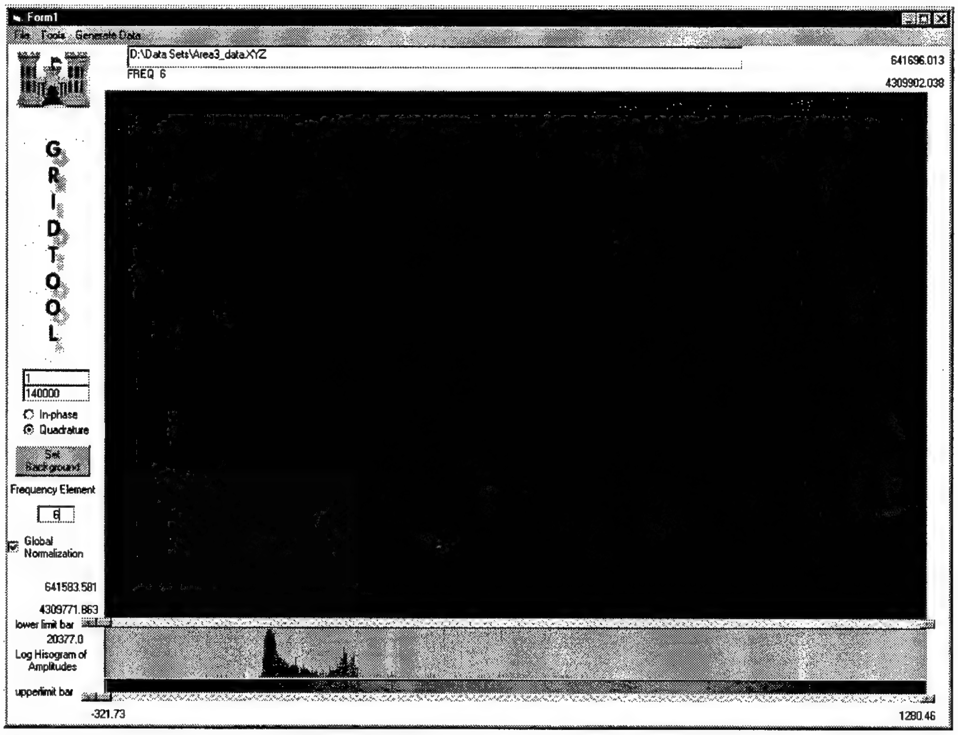


Figure A41. Area 3 quadrature coverage map for 8,190 Hz

Figure A42. Area 3 quadrature coverage map for 20,010 Hz

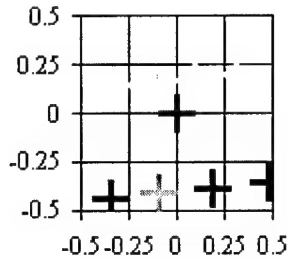
Appendix B
Plots of Data Point Locations and Comparison with Calibration Signatures

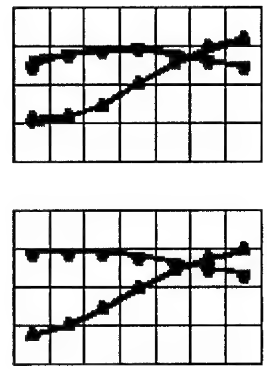
This appendix contains a series of plots for each target in the JPG test. The first plot shows the locations of all data points in a 1-m box centered on the target. The points are represented by plus markers that are color-coded to indicate the closeness of fit of the point to the calibration signature for the target's ordnance type. If no calibration data were available for the ordnance type of the target, all plots are based on the best matching ordnance type for each data point. Yellow indicates a fit error of ≤ 0.0333. Cyan indicates a fit error of > 0.0333 and ≤ 0.0666. Dark blue represents values > 0.0666 and ≤ 0.1. The red marker in the center represents the target. Black represents fit error values of > 0.1.

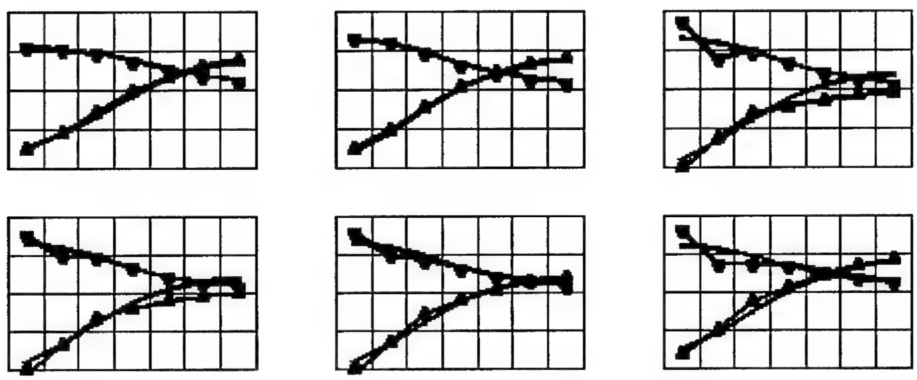
Each remaining plot shows the in-phase and quadrature values for a data point and the calibration signature at the seven frequencies used in the test. The red line represents the calibration data, and the blue line represents the data point. The seven frequencies on the x-axis are 90 Hz, 150 Hz, 330 Hz, 930 Hz, 2,790 Hz, 8,190 Hz, and 20,010 Hz. The y-axis shows normalized PPM.

Target 1-86

Diameter : 4.2in
Depth : 20
Azimuth : 120
Inclination : 45

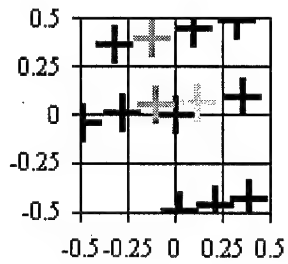


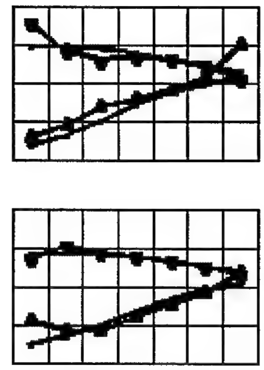


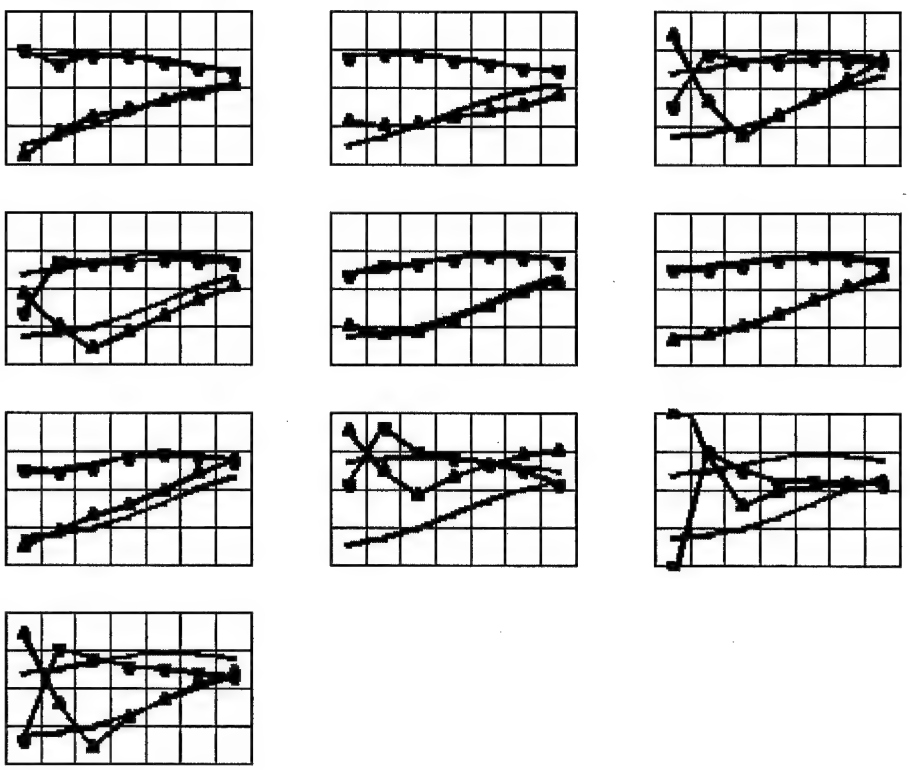


Target 1-88

Diameter : 60mm
Depth : 35
Azimuth : 0
Inclination : 0

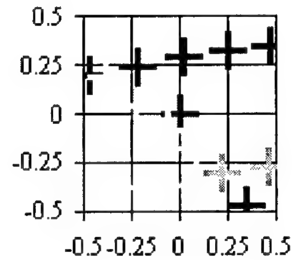


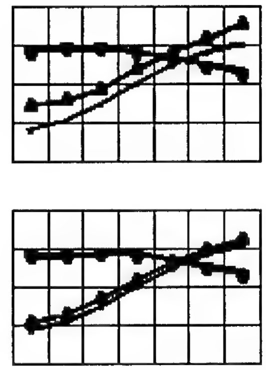


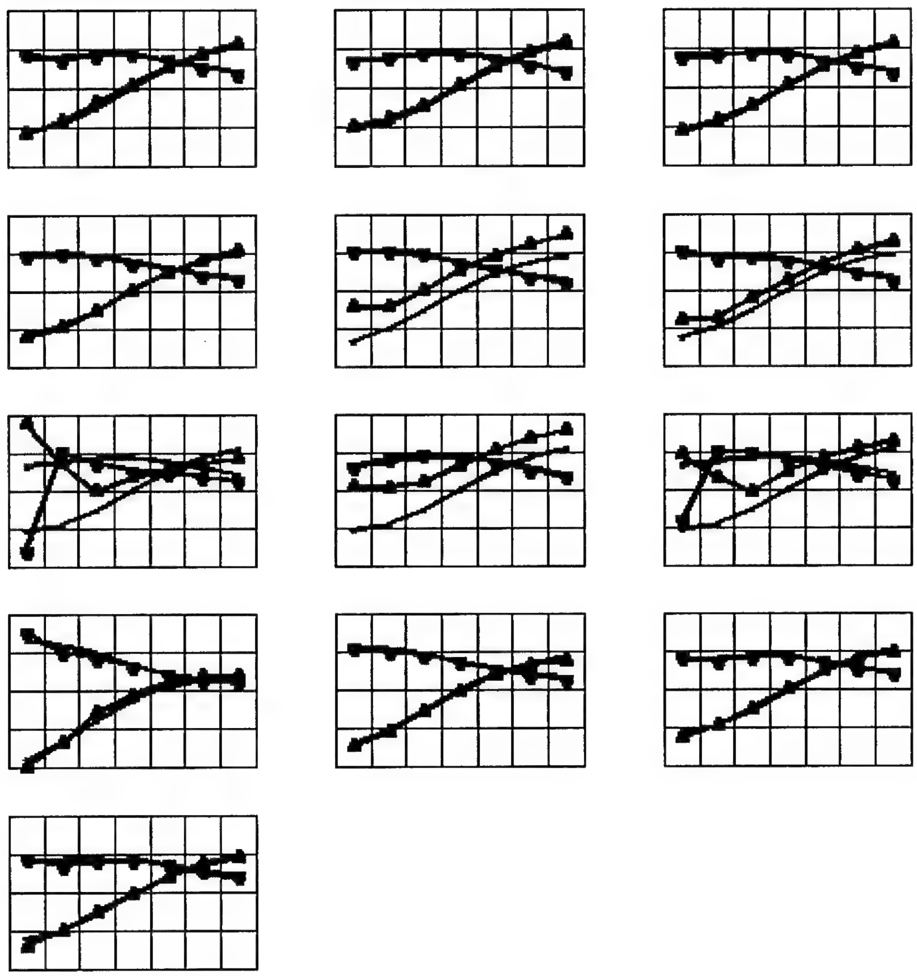


Target 1-90

Diameter : 4.2in
Depth : 35
Azimuth : 270
Inclination : 0

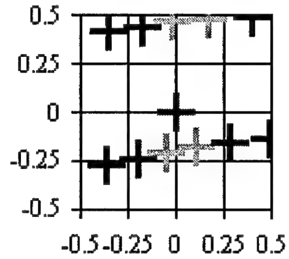


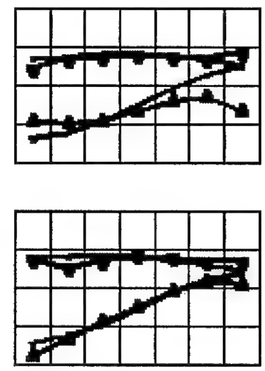


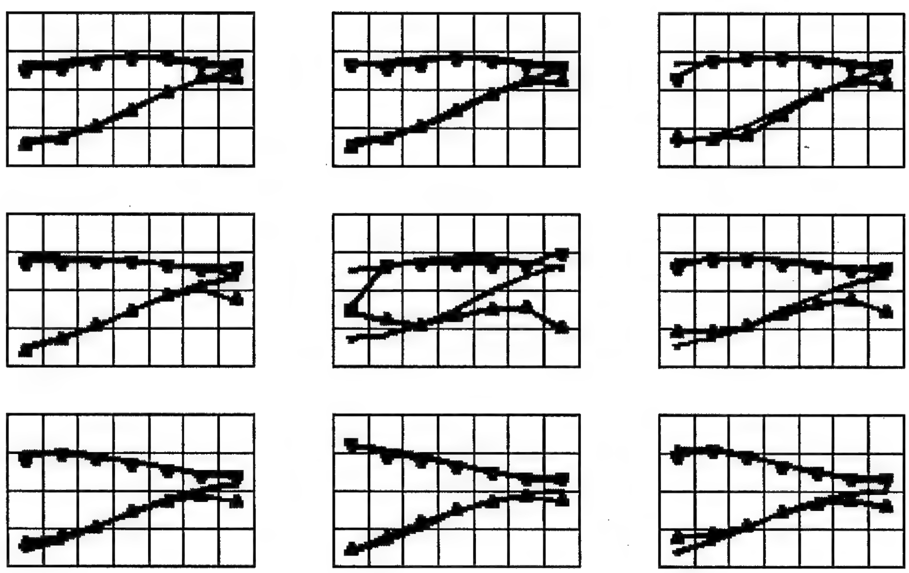


Target 1-92

Diameter : 81mm
Depth : 20
Azimuth : 30
Inclination : 20

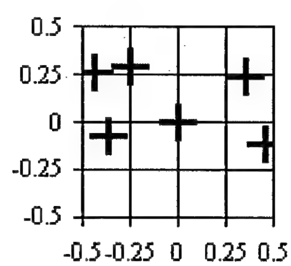


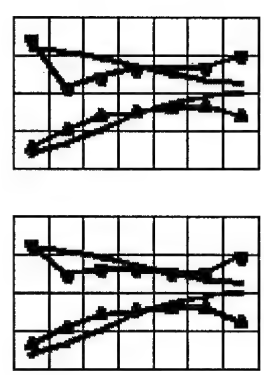


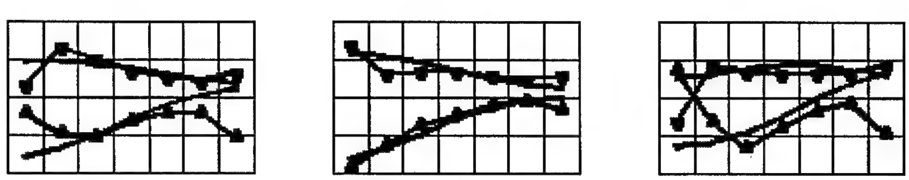


Target 1-94

Diameter : 81mm
Depth : 25
Azimuth : 75
Inclination : 55

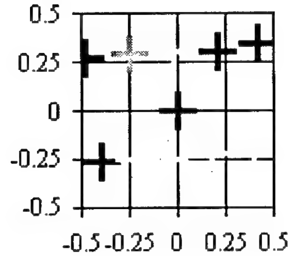


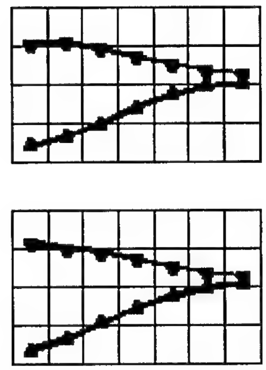


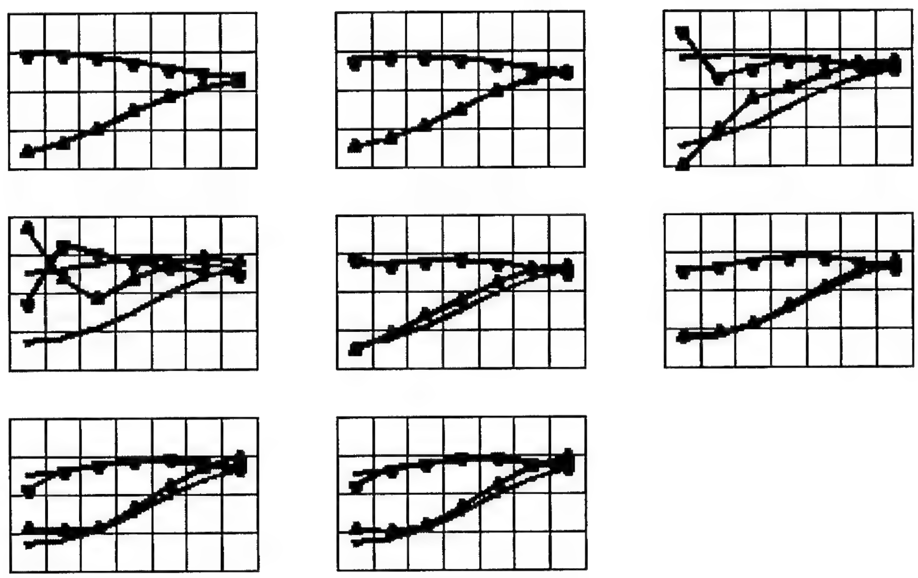


Target 1-96

Diameter : 81mm
Depth : 15
Azimuth : 330
Inclination : 35

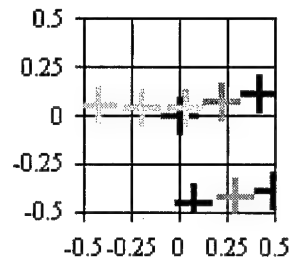


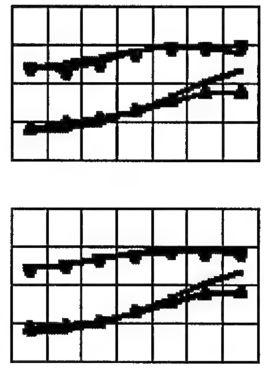


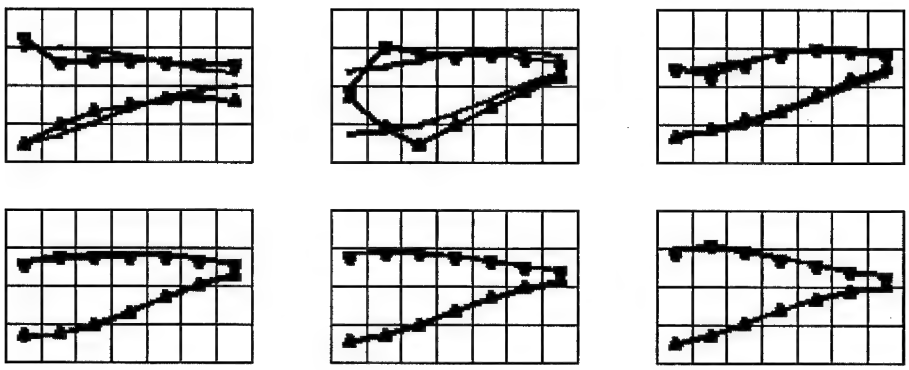


Target 1-98

Diameter : 60mm
Depth : 10
Azimuth : 275
Inclination : 20

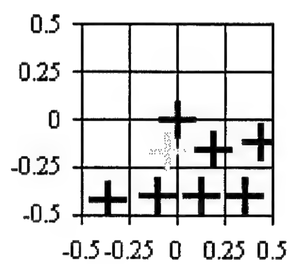


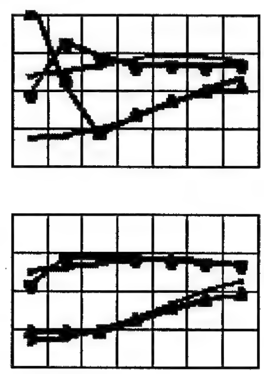


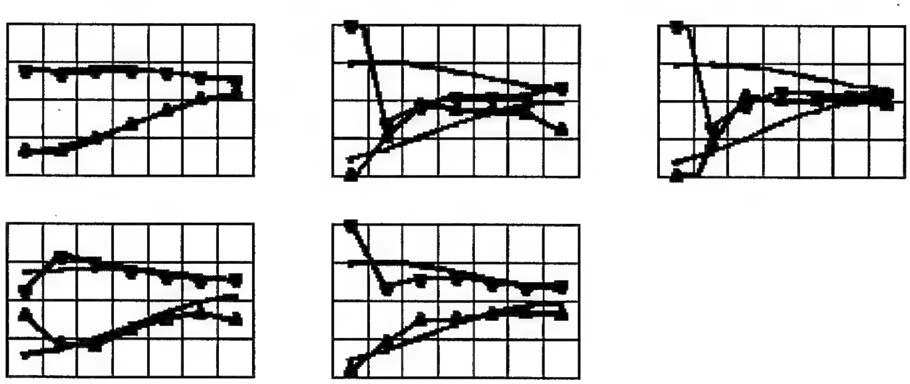


Target 1-100

Diameter : 60mm
Depth : 20
Azimuth : 195
Inclination : 30

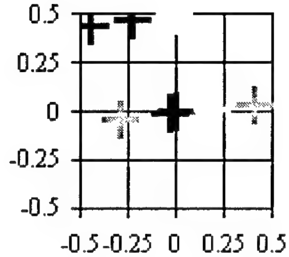


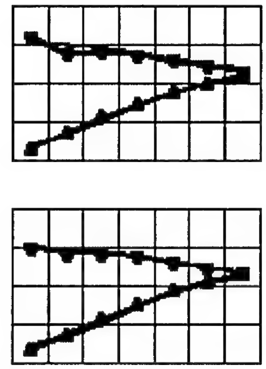


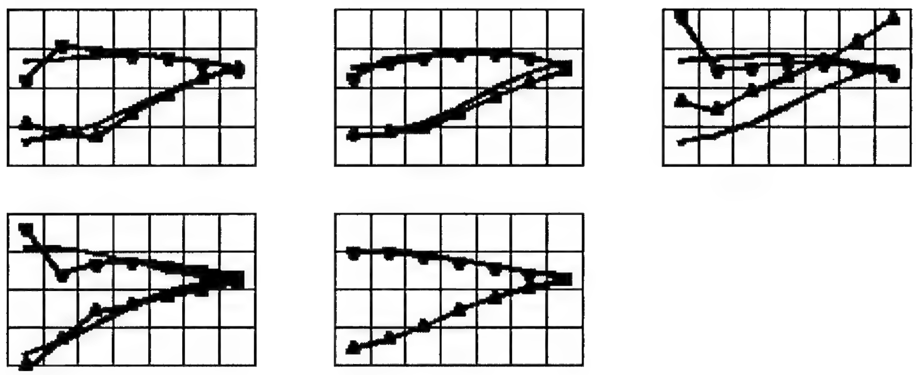


Target 1-102

Diameter : 81mm
Depth : 25
Azimuth : 210
Inclination : 45

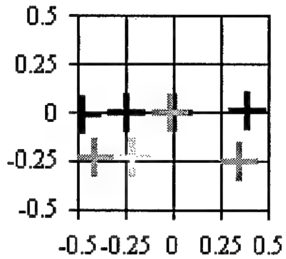


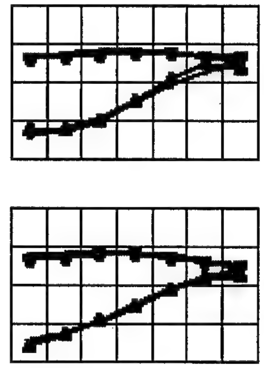


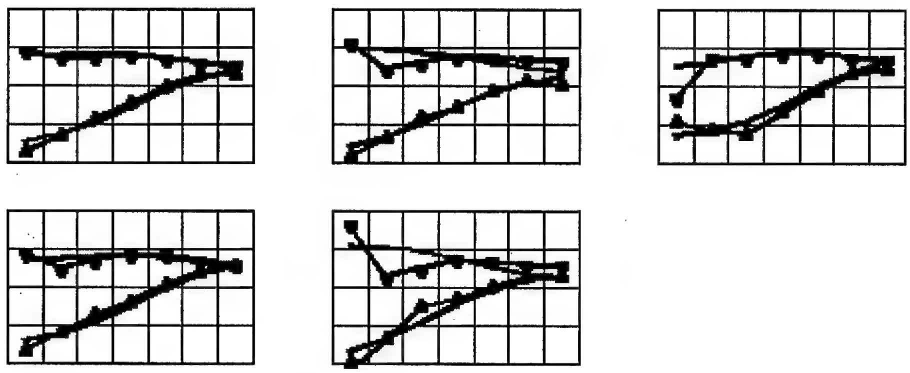


Target 1-104

Diameter : 81mm
Depth : 35
Azimuth : 180
Inclination : 0

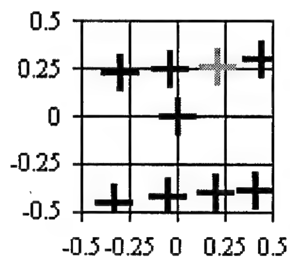


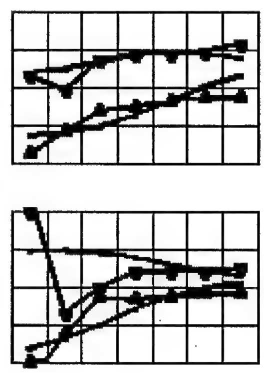


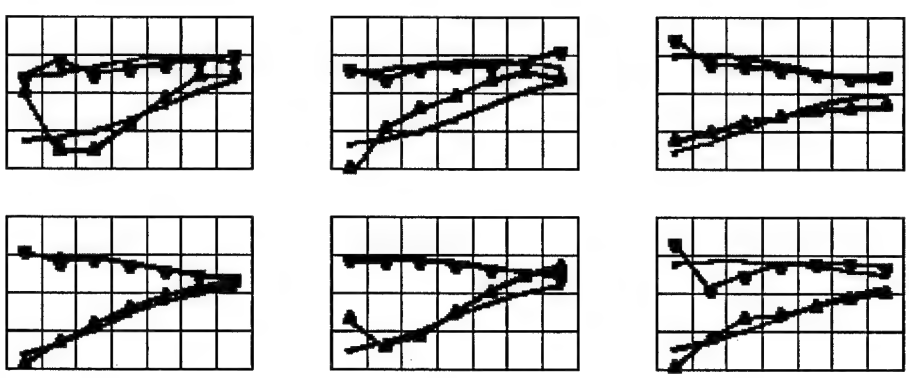


Target 1-106

Diameter : 60mm
Depth : 25
Azimuth : 75
Inclination : 35

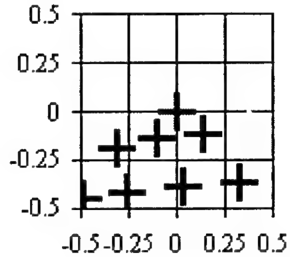


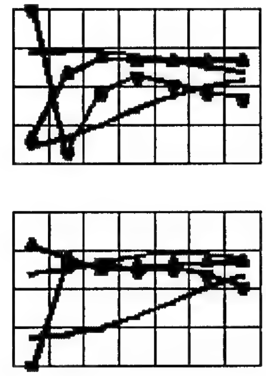


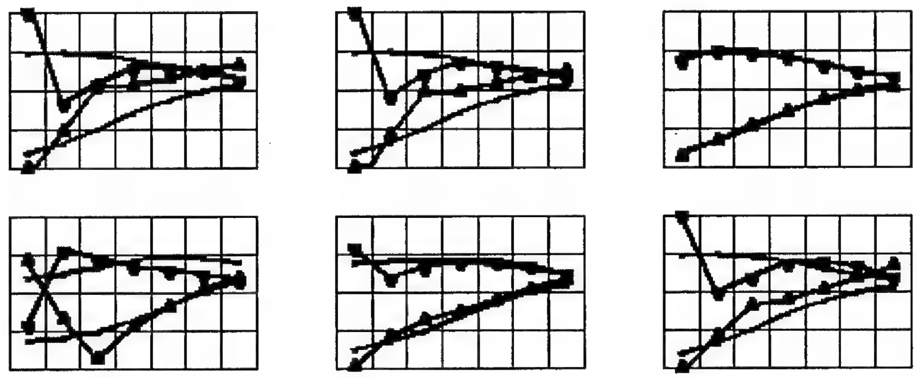


Target 1-108

Diameter : 60mm
Depth : 20
Azimuth : 100
Inclination : 45

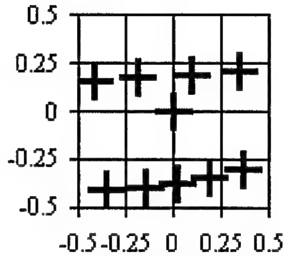


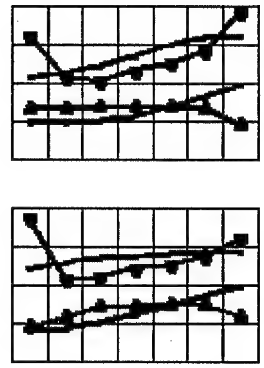


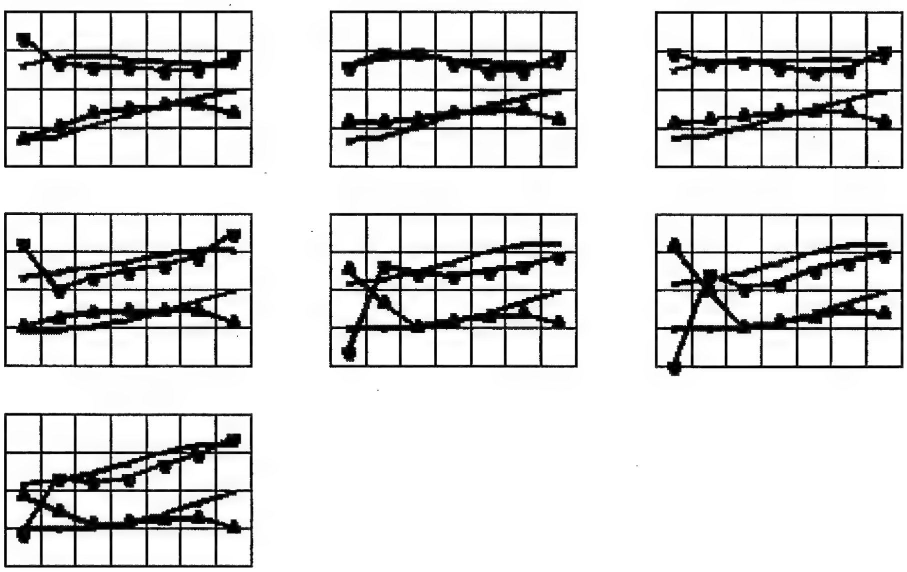


Target 1-112

Diameter : 20mm
Depth : 10
Azimuth : 30
Inclination : 10

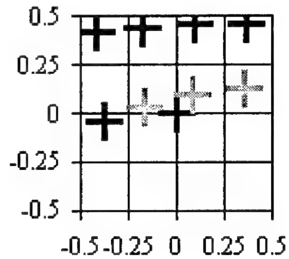


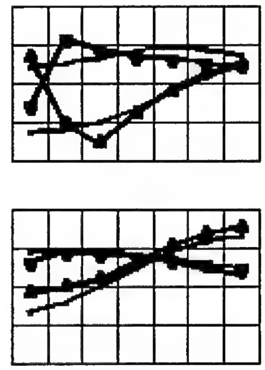


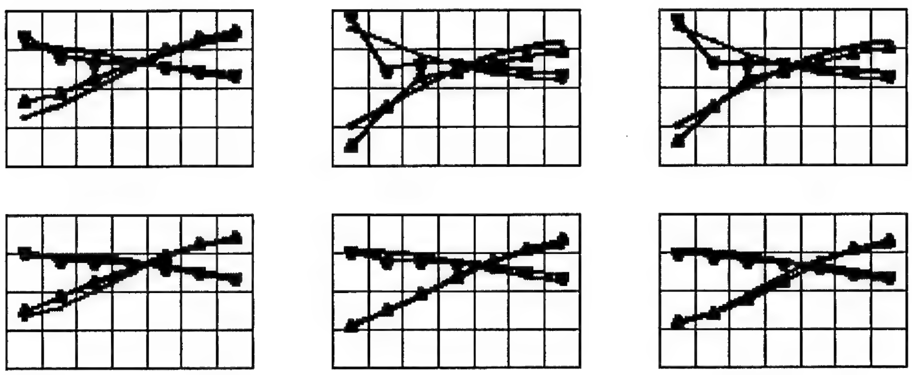


Target 1-113

Diameter : 105mm
Depth : 50
Azimuth : 120
Inclination : 30

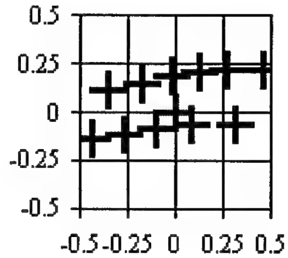


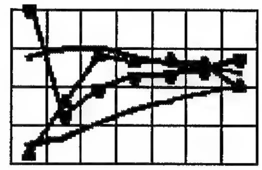


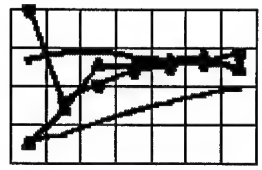


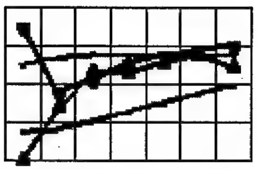
Target 1-114

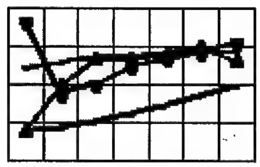
Diameter : 20mm
Depth : 15
Azimuth : 175
Inclination : 20

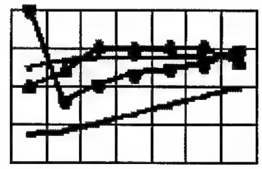


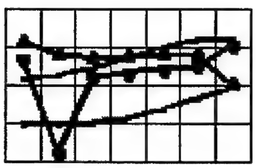


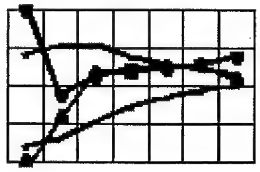


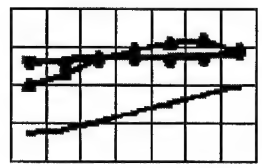


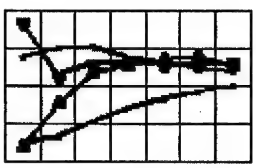


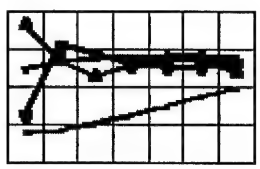


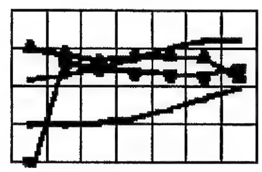






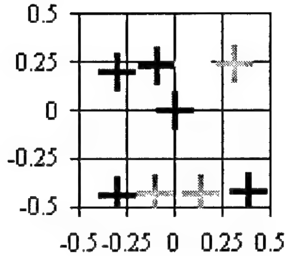


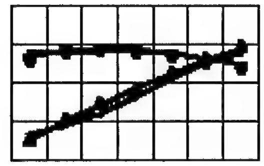


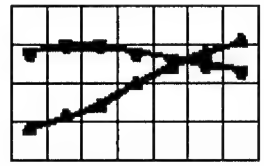


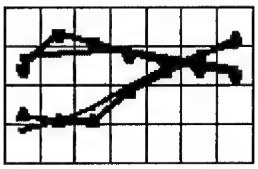
Target 1-115

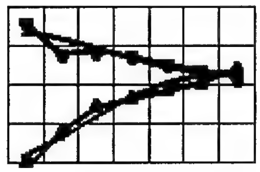
Diameter : 76mm
Depth : 25
Azimuth : 270
Inclination : 30

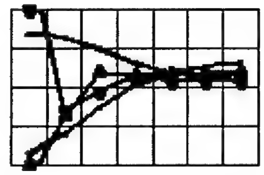


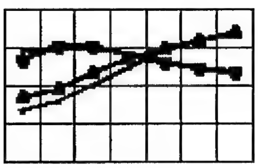


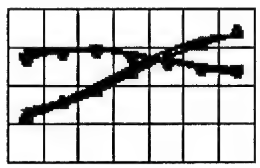


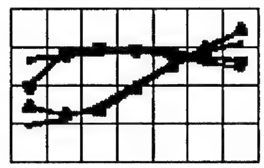






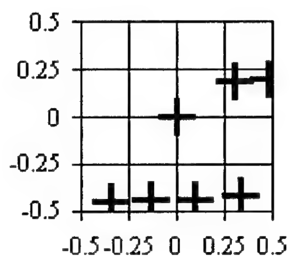


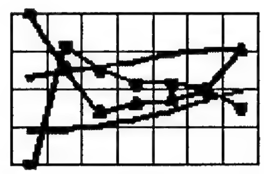


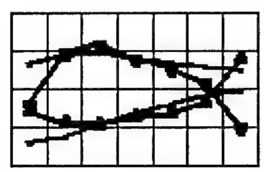


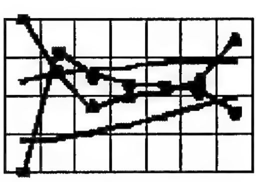
Target 1-116

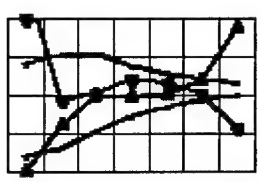
Diameter : 20mm
Depth : 15
Azimuth : 0
Inclination : 0

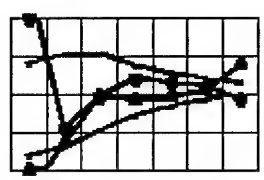


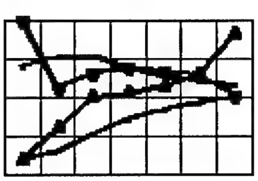






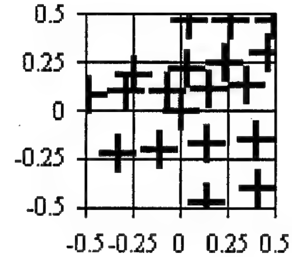


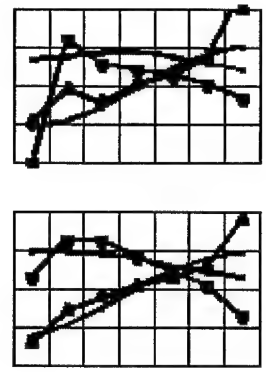


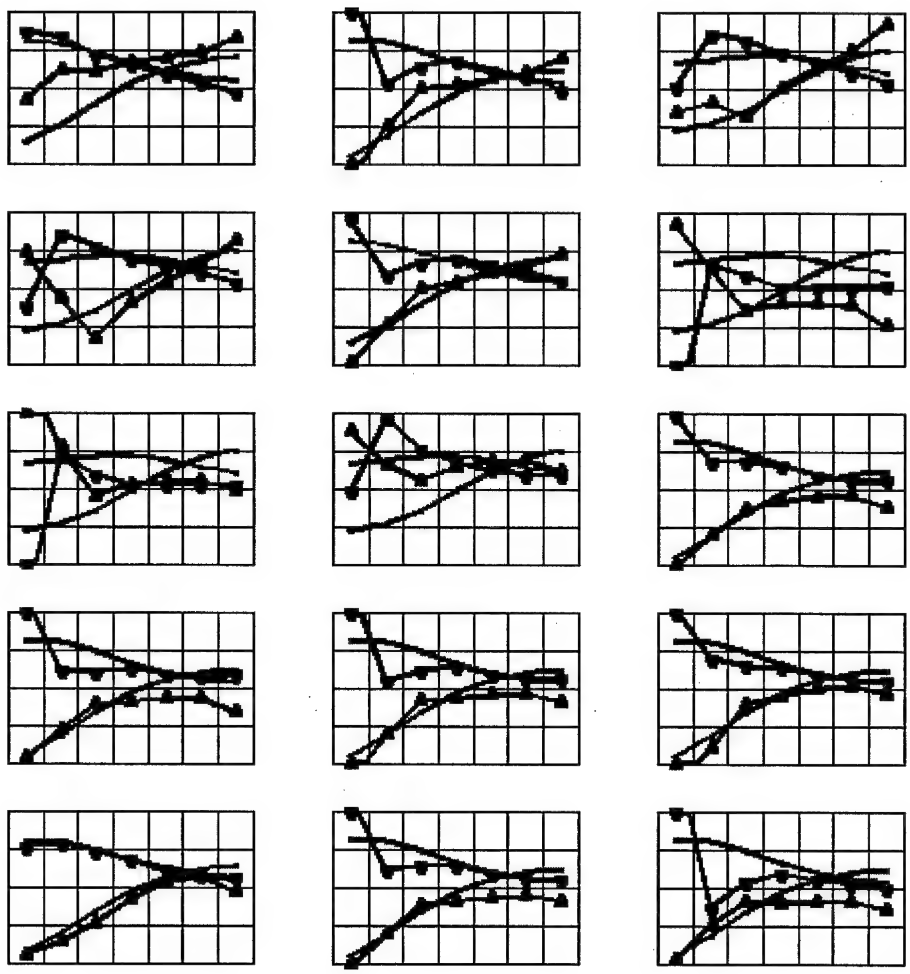


Target 1-117

Diameter : 152mm
Depth : 90
Azimuth : 0
Inclination : 45

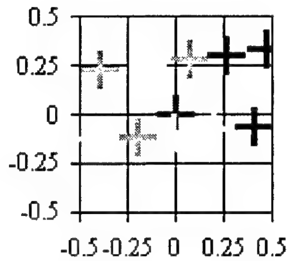


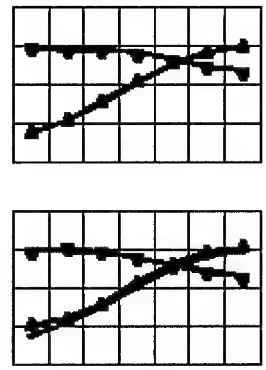


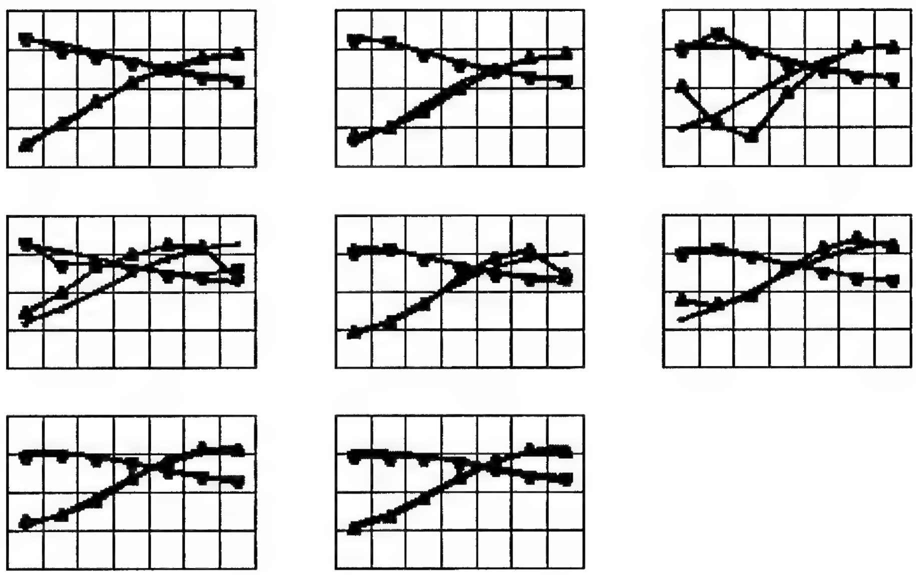


Target 1-118

Diameter : 5.0in
Depth : 45
Azimuth : 120
Inclination : 30

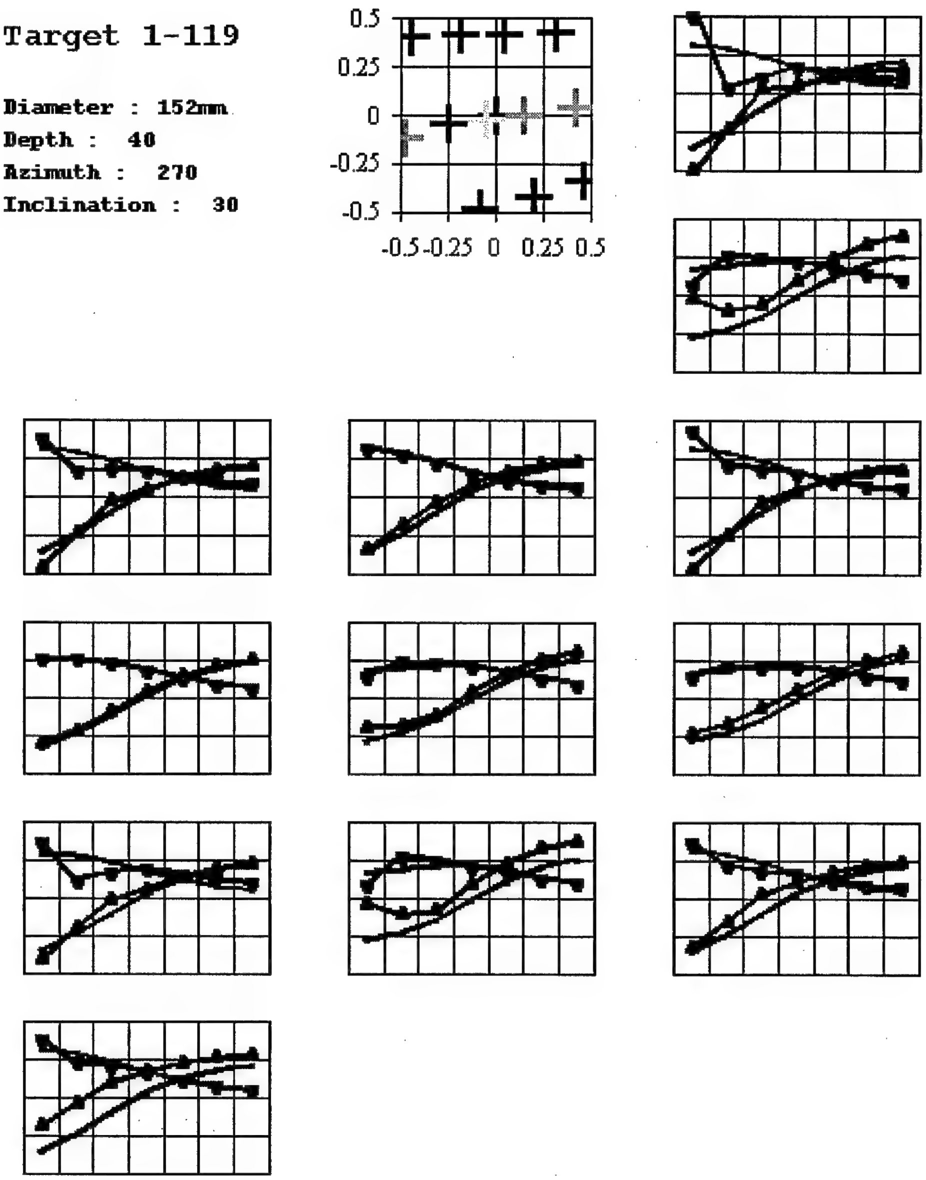






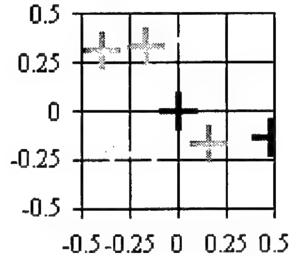
Target 1-119

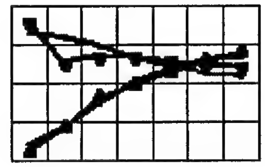
Diameter : 152mm
Depth : 40
Azimuth : 270
Inclination : 30

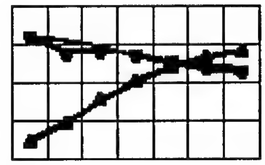


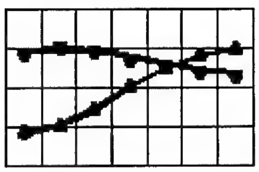
Target 1-120

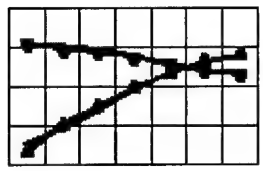
Diameter : 76mm
Depth : 25
Azimuth : 0
Inclination : 20

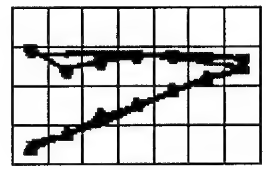


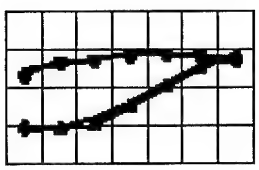


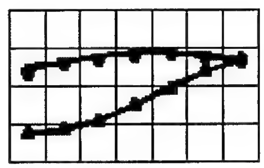






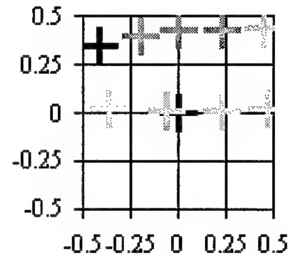


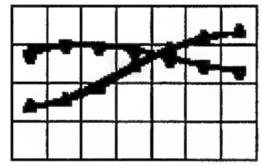


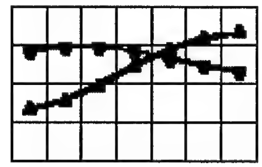


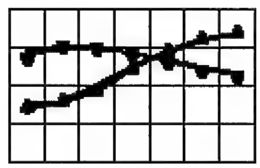
Target 1-121

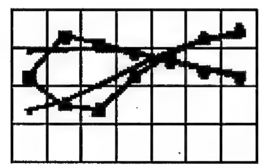
Diameter : 155mm
Depth : 50
Azimuth : 200
Inclination : 0

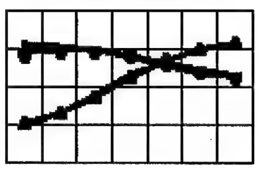


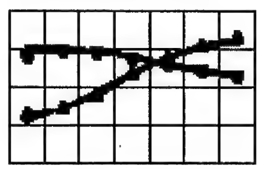


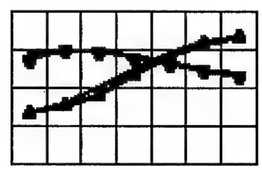


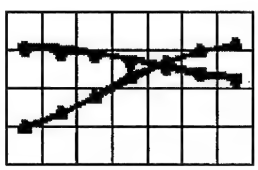






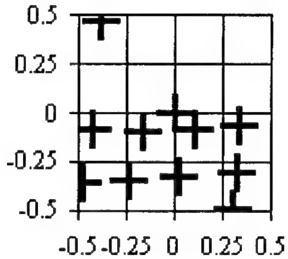


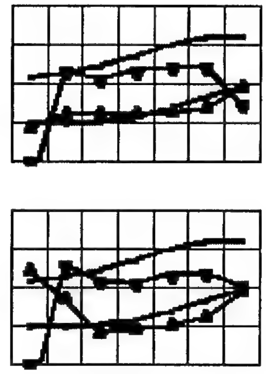


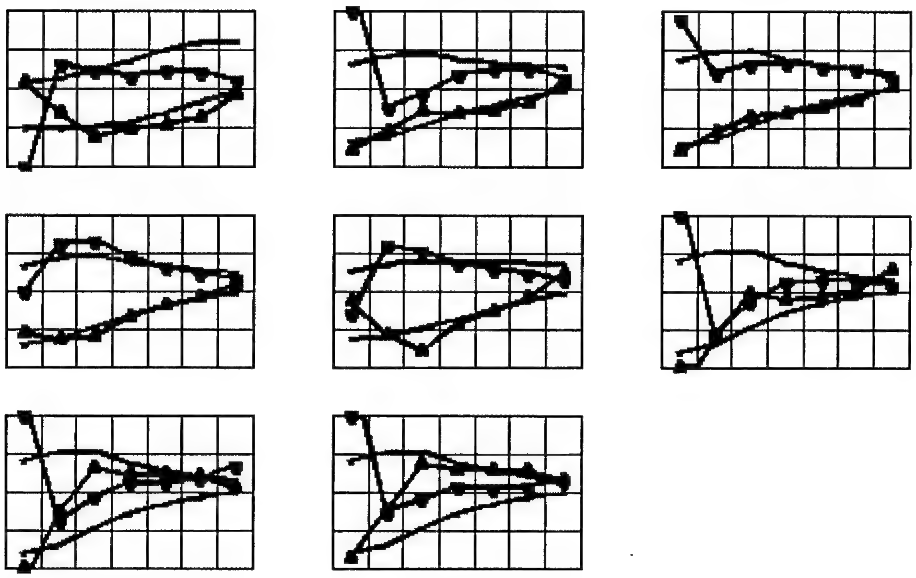


Target 1-123

Diameter : 20mm
Depth : 0
Azimuth : 0
Inclination : 90

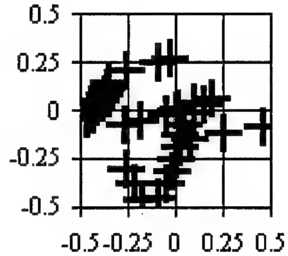


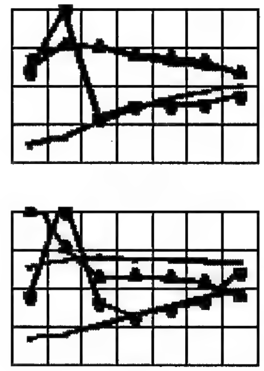


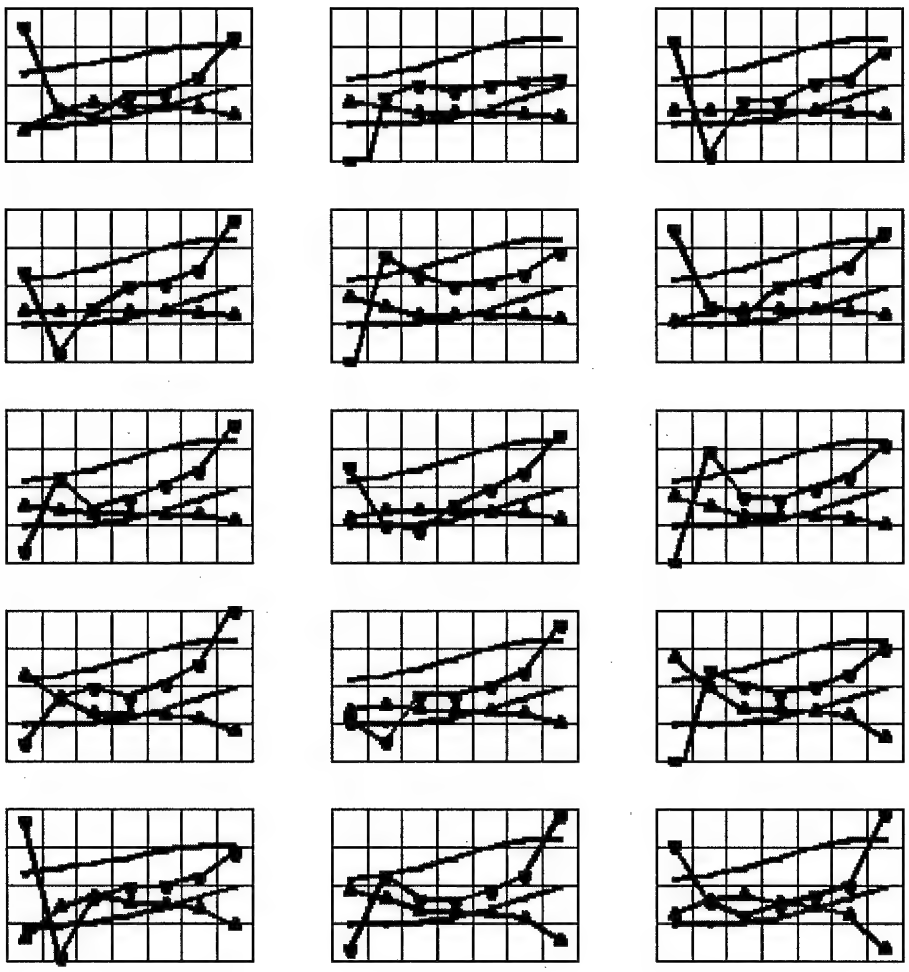


Target 1-124

Diameter : 20mm
Depth : 0
Azimuth : 0
Inclination : -90

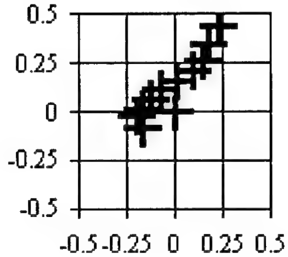


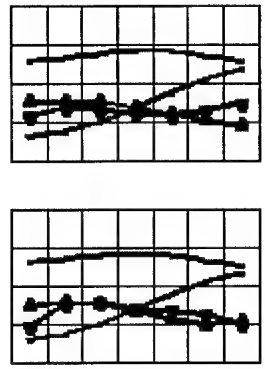


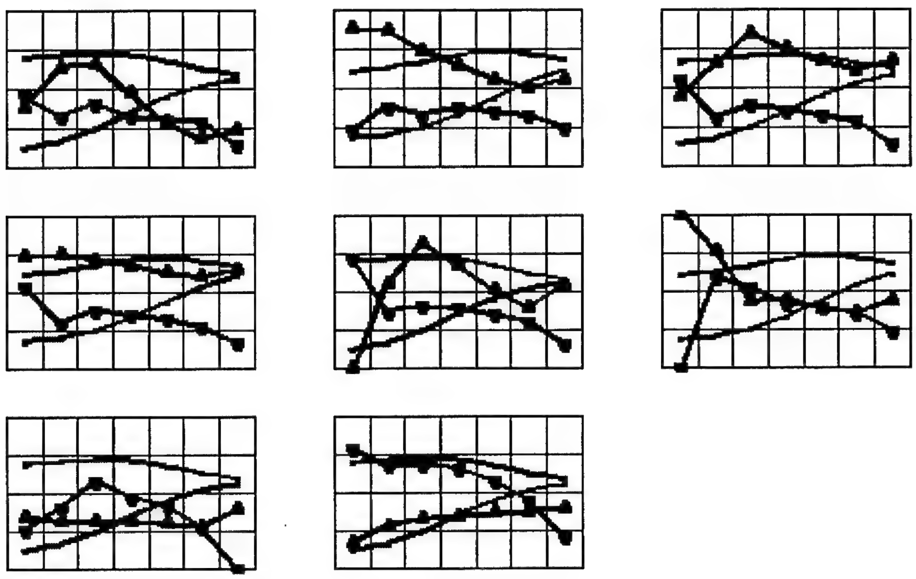


Target 1-126

Diameter : 57mm
Depth : 20
Azimuth : 120
Inclination : 30

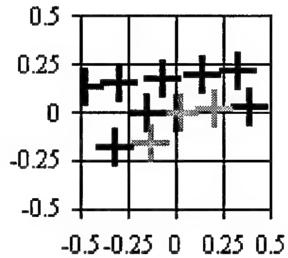


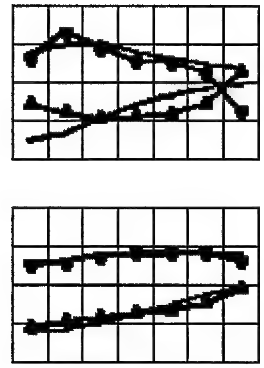


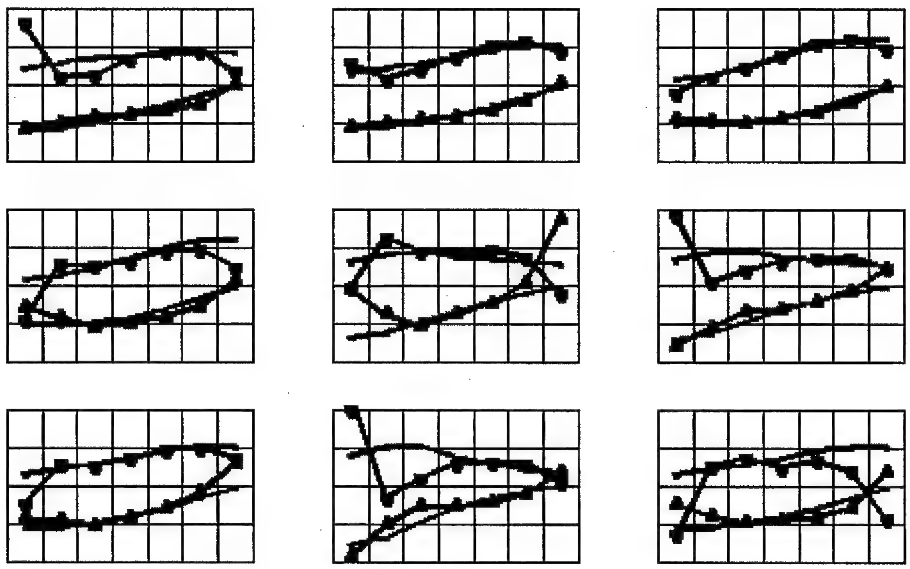


Target 1-128

Diameter : 20mm
Depth : 10
Azimuth : 0
Inclination : 0

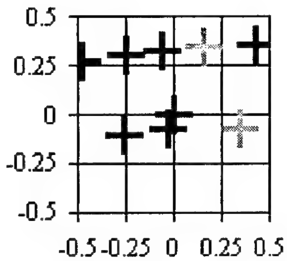


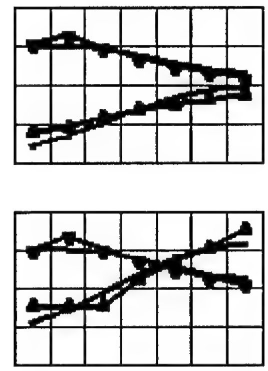


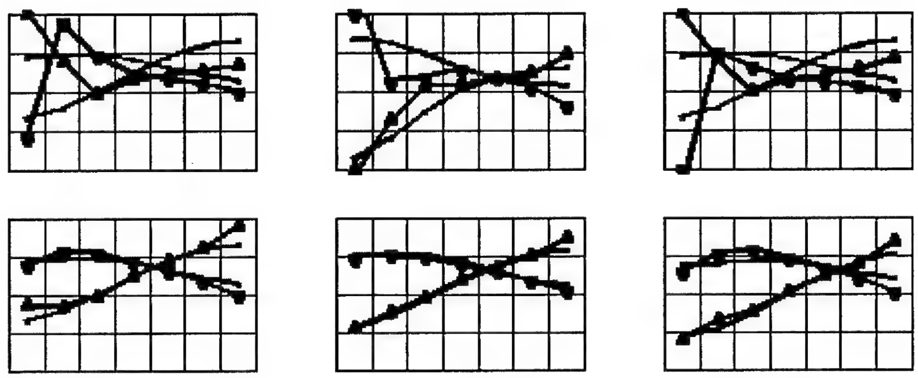


Target 1-130

Diameter : 5.0in
Depth : 70
Azimuth : 180
Inclination : 30

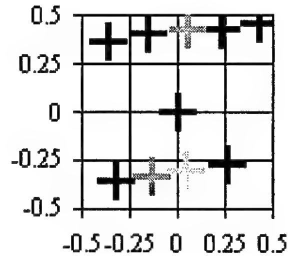


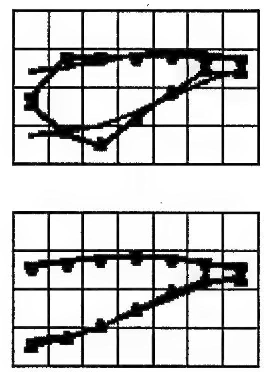


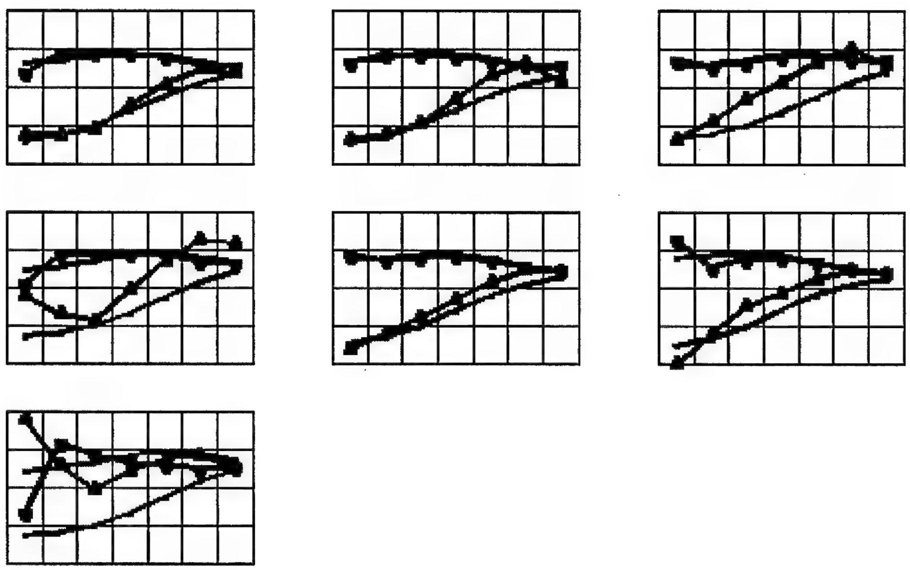


Target 1-132

Diameter : 57mm
Depth : 25
Azimuth : 180
Inclination : 0

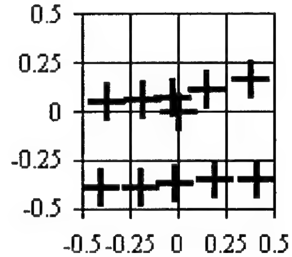


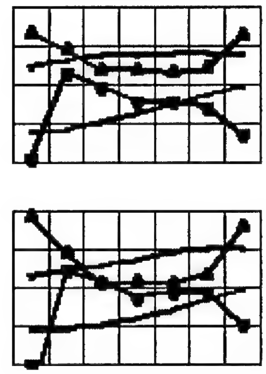


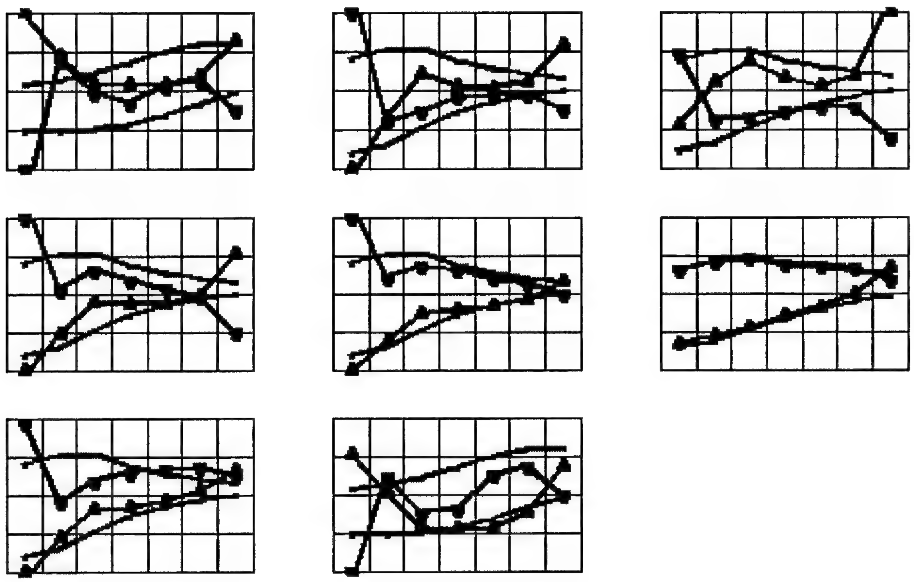


Target 1-134

Diameter : 20mm
Depth : 5
Azimuth : 120
Inclination : 30

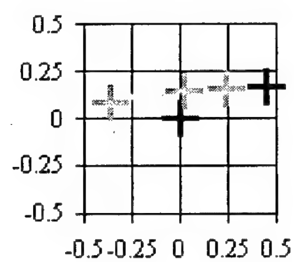


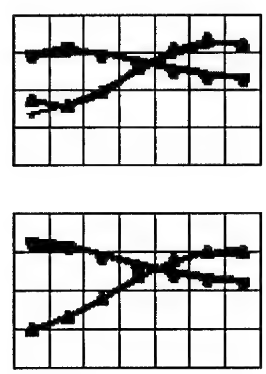


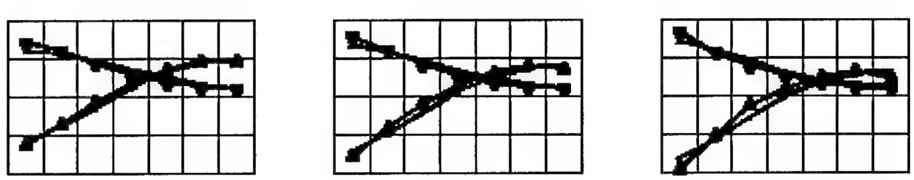


Target 1-136

Diameter : 155mm
Depth : 50
Azimuth : 90
Inclination : 75

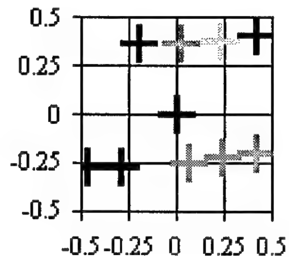


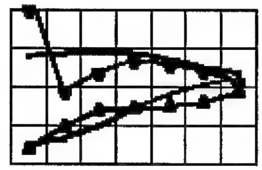


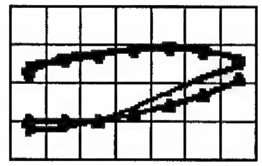


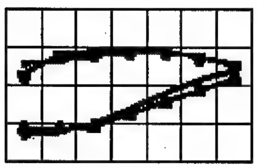
Target 1-138

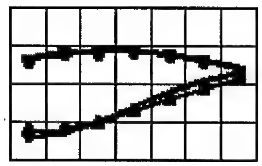
Diameter : 57mm
Depth : 15
Azimuth : 95
Inclination : 45

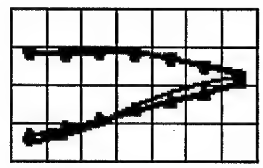


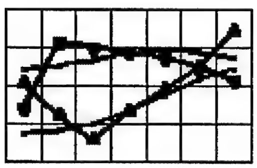


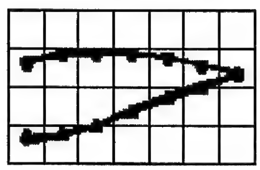


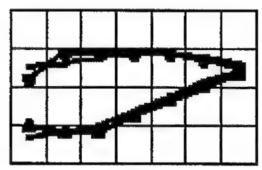


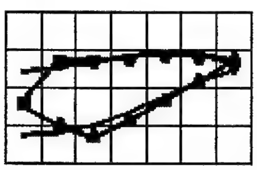






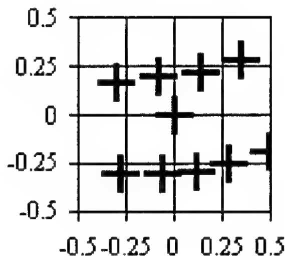


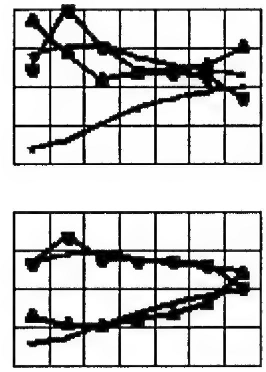


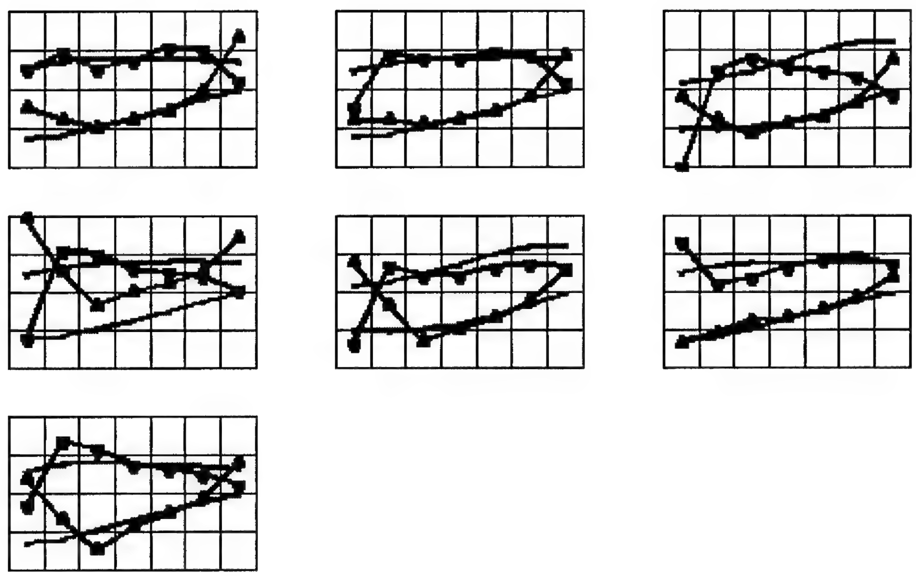


Target 1-140

Diameter : 20mm
Depth : 5
Azimuth : 275
Inclination : 15

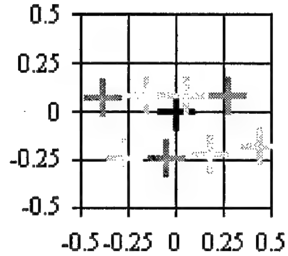


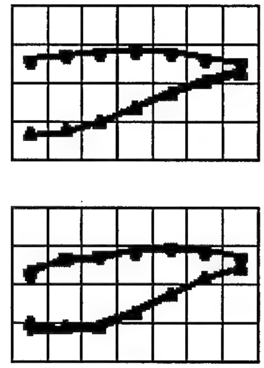


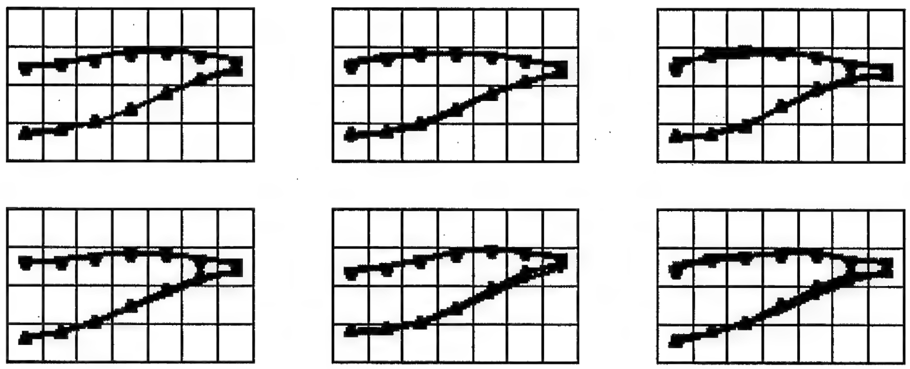


Target 1-142

Diameter : 57mm
Depth : 15
Azimuth : 265
Inclination : 45

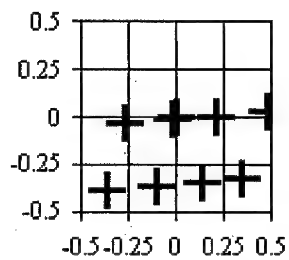


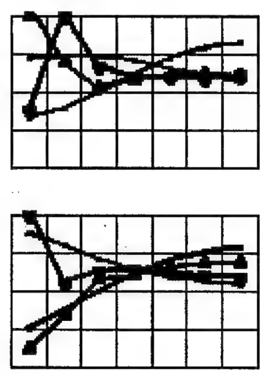


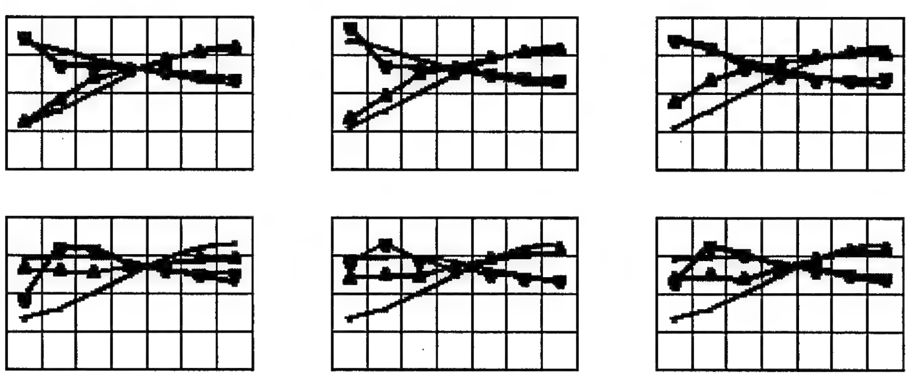


Target 1-144

Diameter : 105mm
Depth : 50
Azimuth : 180
Inclination : 0

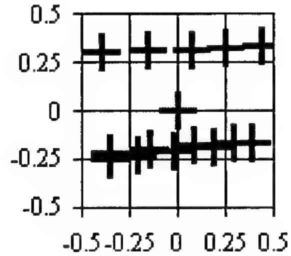


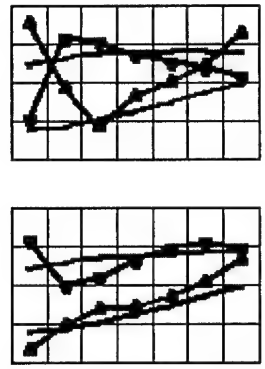


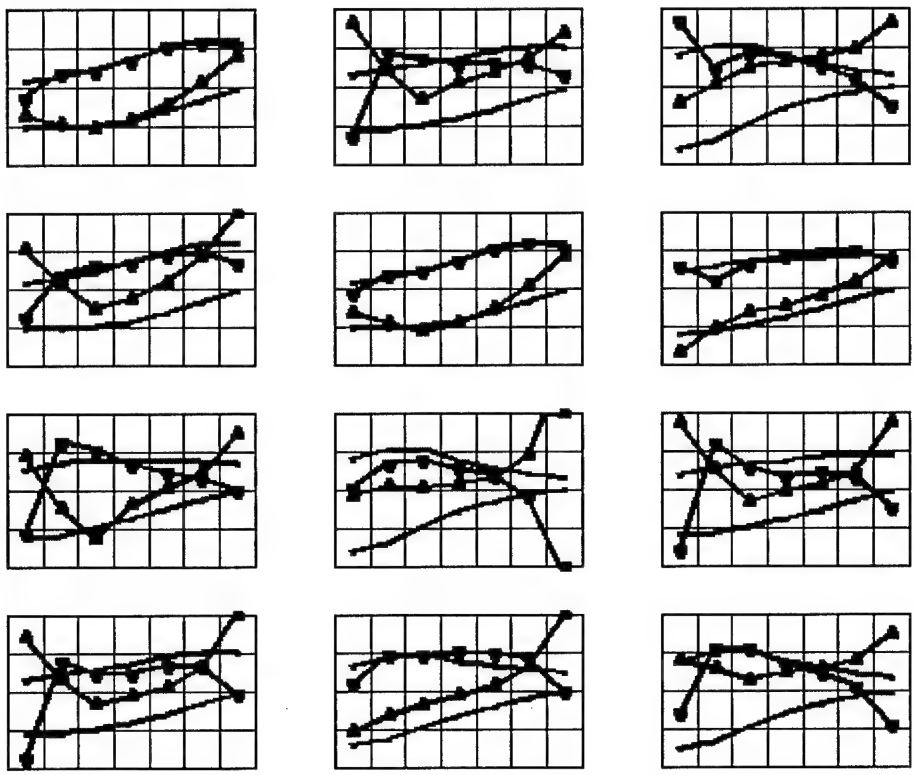


Target 1-146

Diameter : 20mm
Depth : 5
Azimuth : 270
Inclination : 0

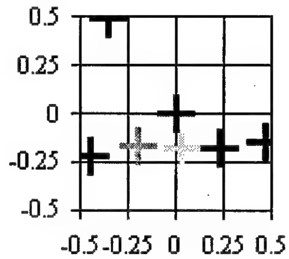


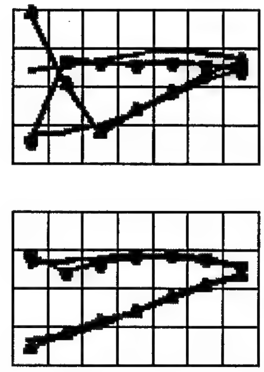


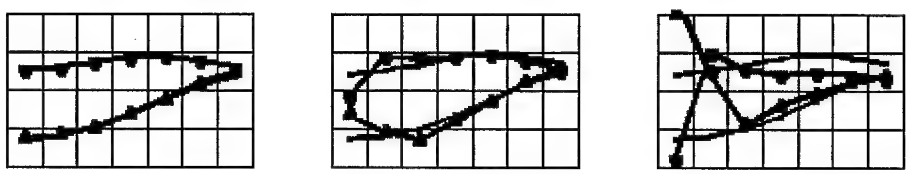


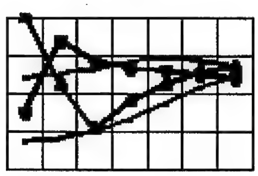
Target 1-147

Diameter : 57mm
Depth : 25
Azimuth : 0
Inclination : 0



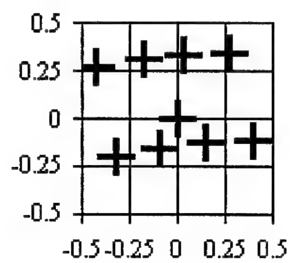


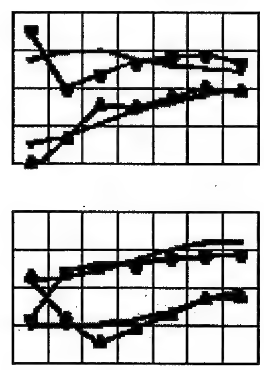


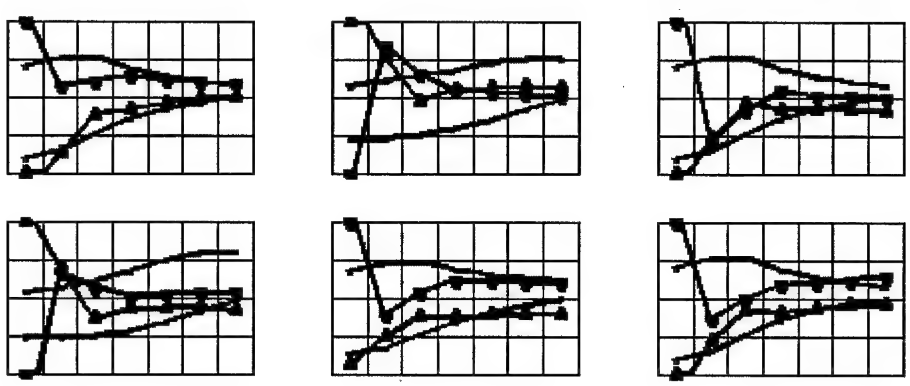


Target 1-148

Diameter : 20mm
Depth : 10
Azimuth : 235
Inclination : 45

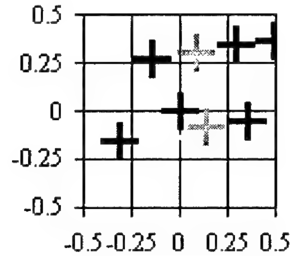


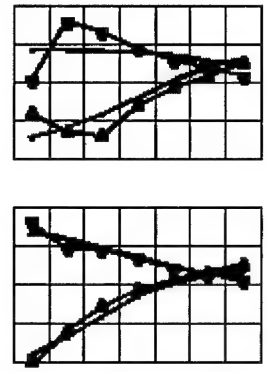


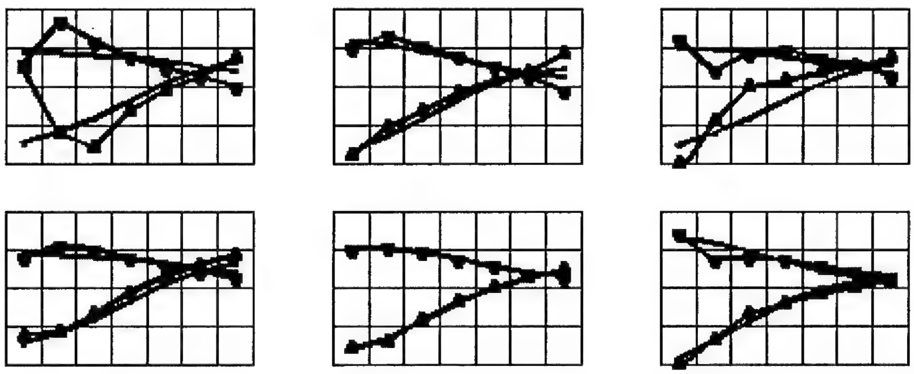


Target 1-149

Diameter : 2.75in
Depth : 50
Azimuth : 30
Inclination : 55

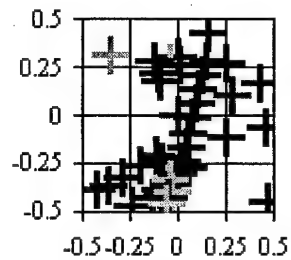


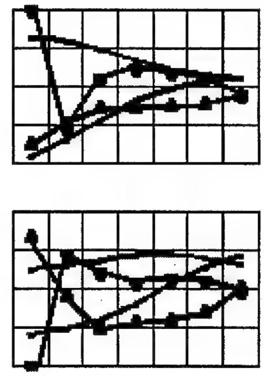


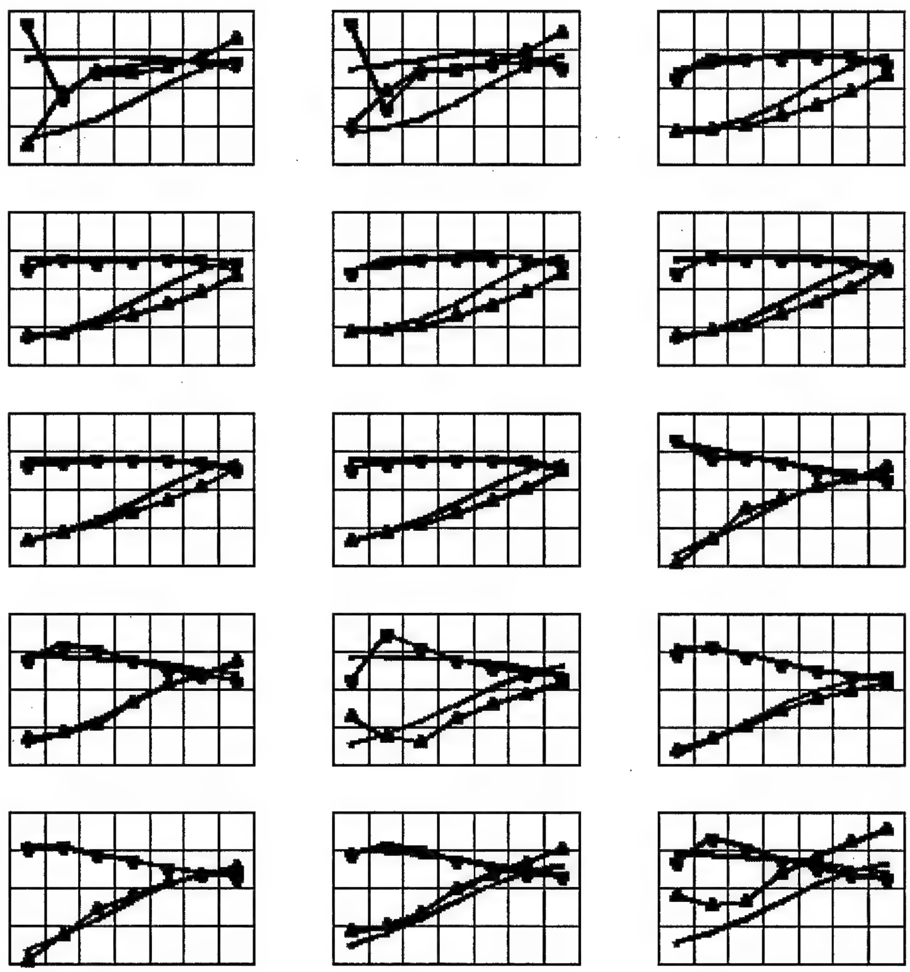


Target 1-150

Diameter : 2.75in
Depth : 70
Azimuth : 275
Inclination : 45

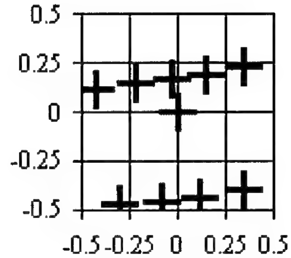


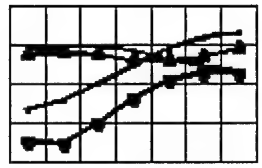


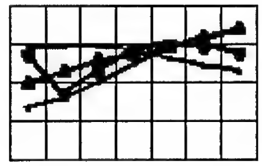


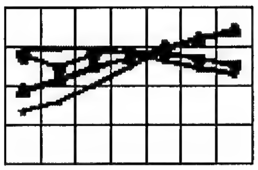
Target 1-151

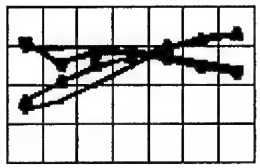
Diameter : 76mm
Depth : 25
Azimuth : 150
Inclination : 45

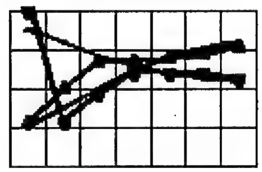


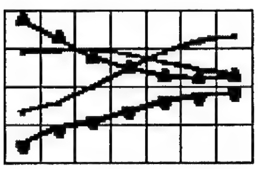


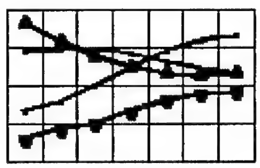


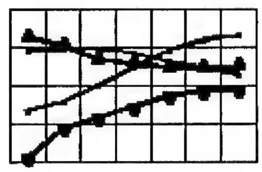


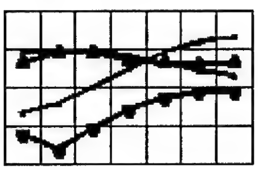






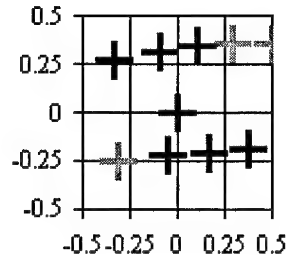


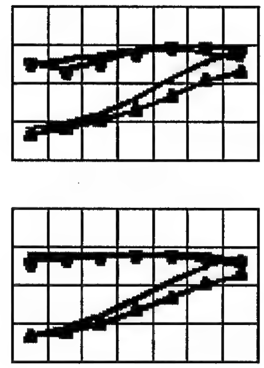


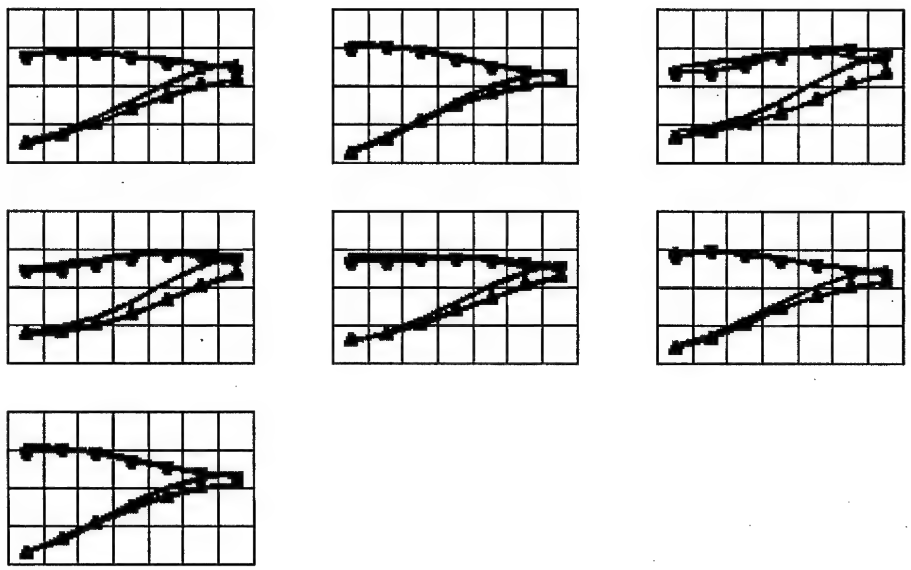


Target 1-152

Diameter : 2.75in
Depth : 15
Azimuth : 30
Inclination : 0

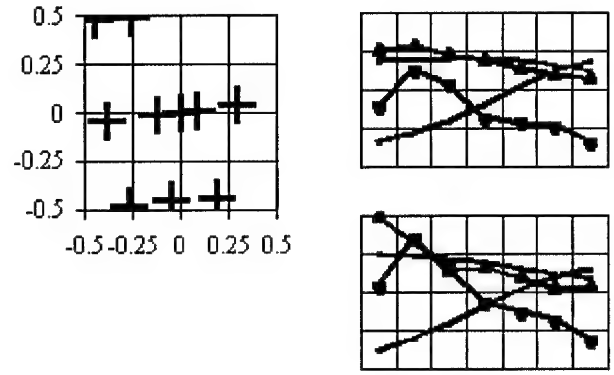


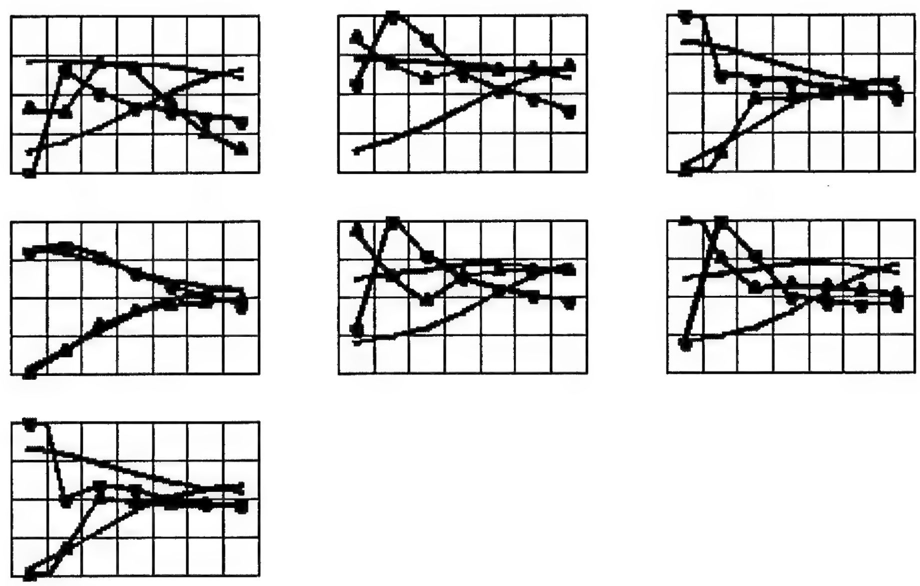




Target 1-153

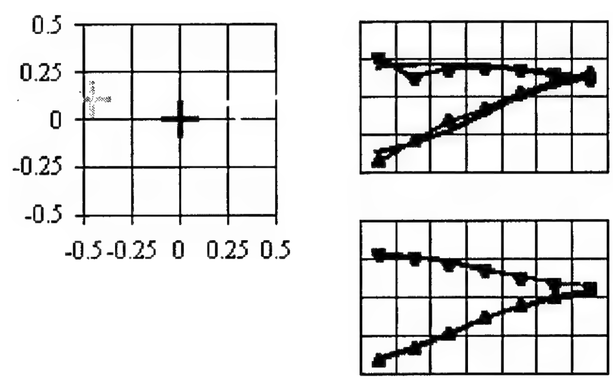
Diameter : 2.75in
Depth : 76
Azimuth : 0
Inclination : 90

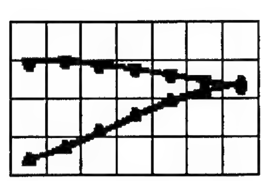




Target 2-112

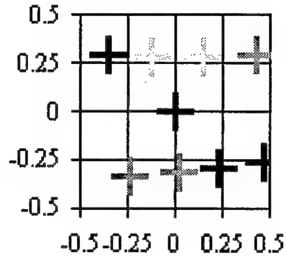
Diameter : 81mm
Depth : 10
Azimuth : 0
Inclination : 90

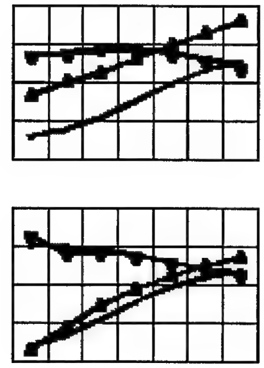


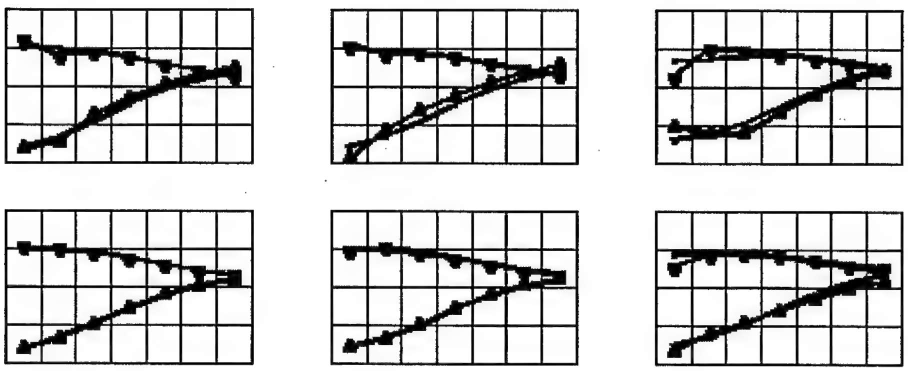


Target 2-114

Diameter : 81mm
Depth : 20
Azimuth : 0
Inclination : -90

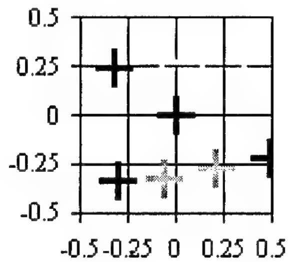


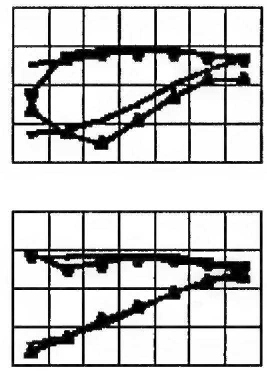


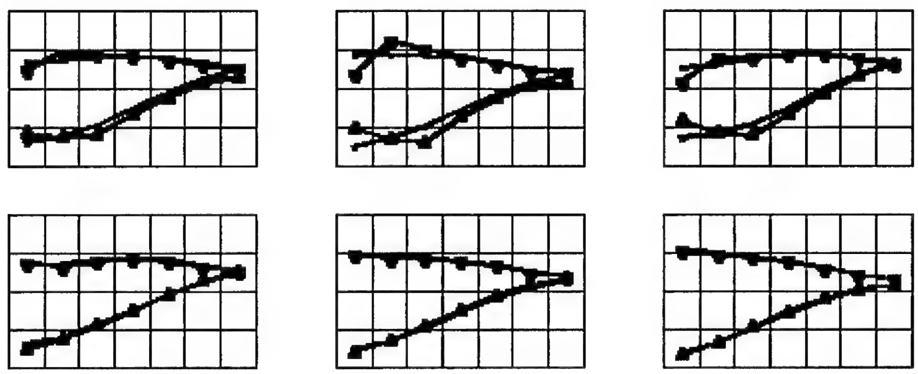


Target 2-116

Diameter : 81mm
Depth : 30
Azimuth : 45
Inclination : 0

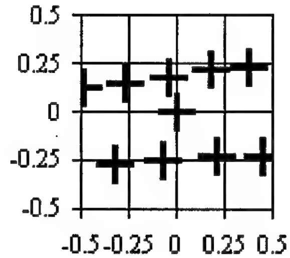


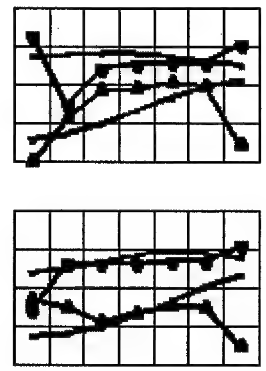


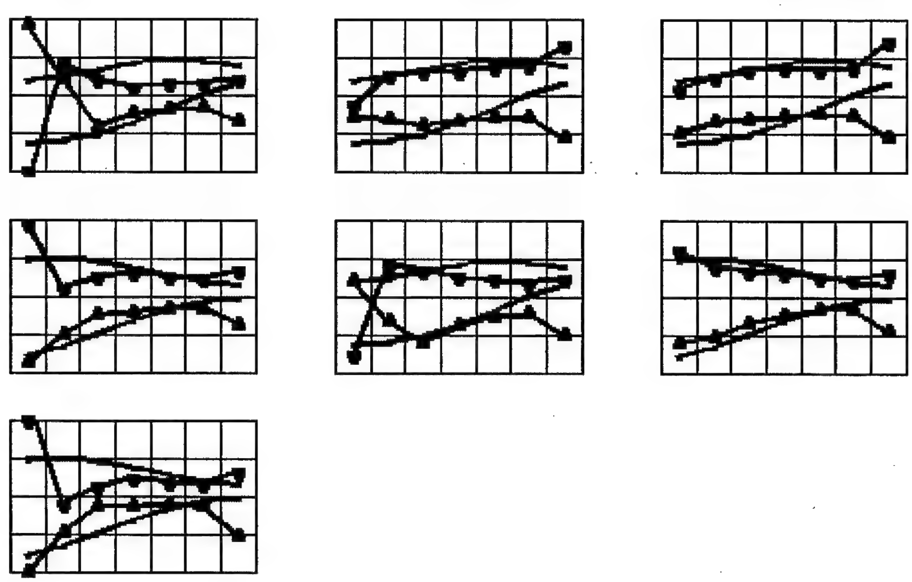


Target 2-118

Diameter : 60mm
Depth : 35
Azimuth : 0
Inclination : 45

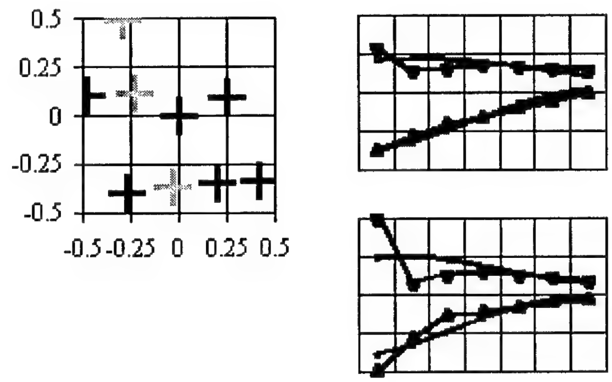


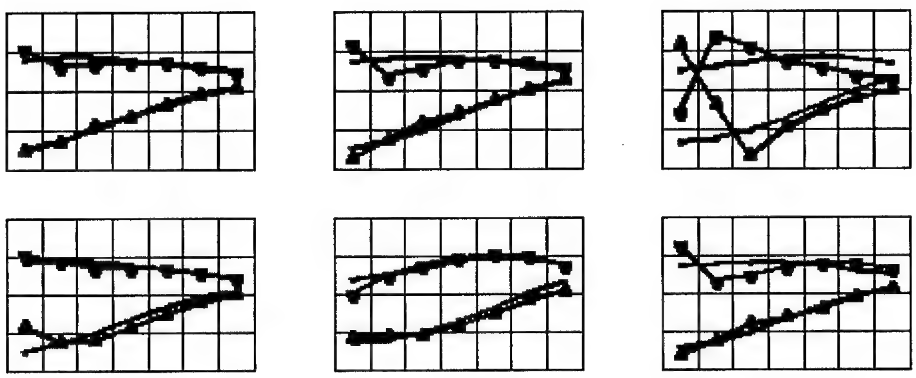




Target 2-120

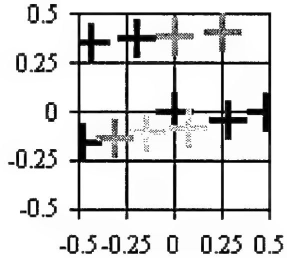
Diameter : 60mm
Depth : 30
Azimuth : 270
Inclination : 0

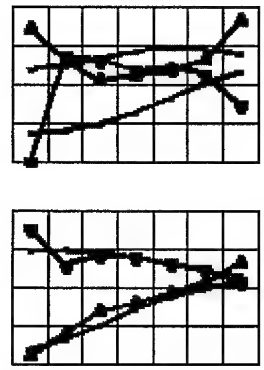


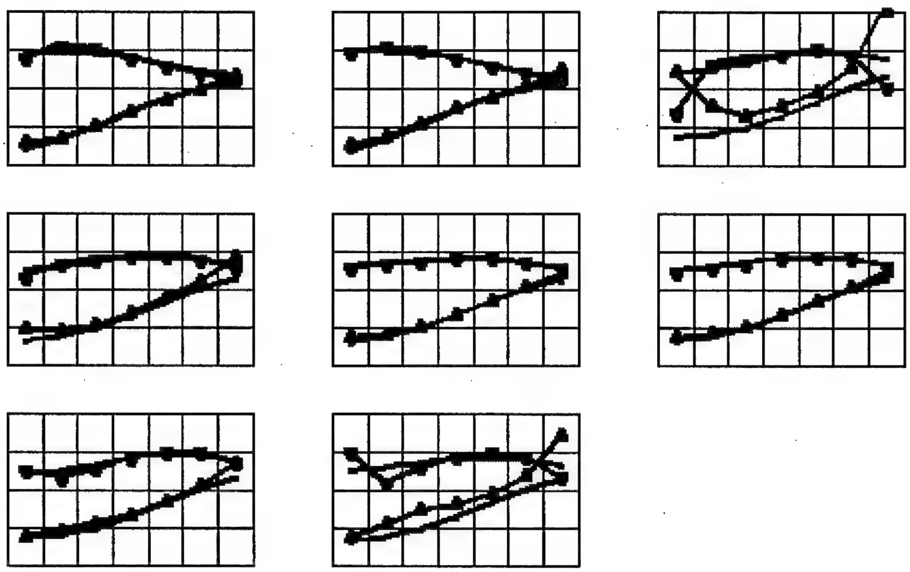


Target 2-122

Diameter : 60mm
Depth : 10
Azimuth : 180
Inclination : 30

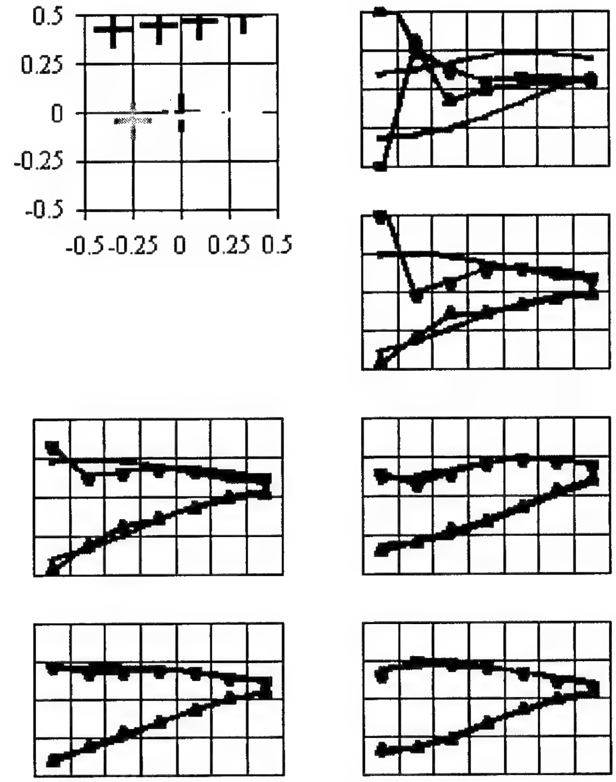


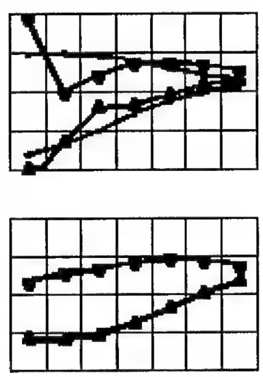




Target 2-124

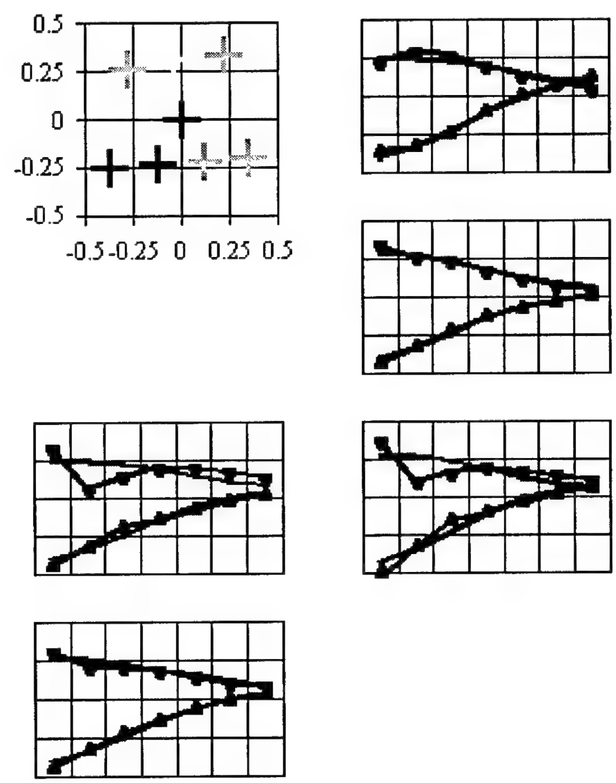
Diameter : 60mm
Depth : 20
Azimuth : 330
Inclination : 10

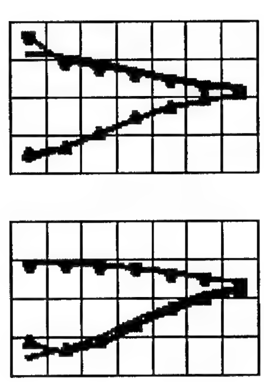




Target 2-126

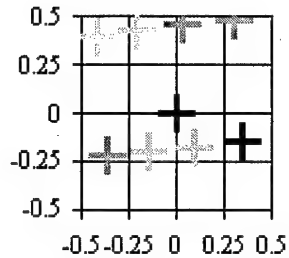
Diameter : 81mm
Depth : 35
Azimuth : 45
Inclination : 45

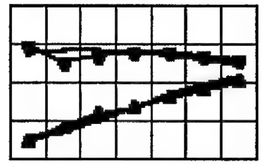


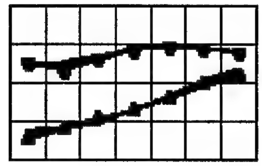


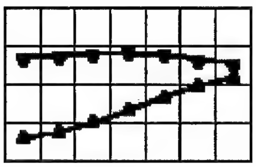
Target 2-128

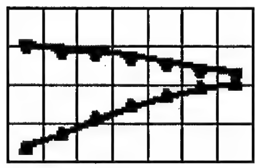
Diameter : 60mm
Depth : 10
Azimuth : 95
Inclination : 20

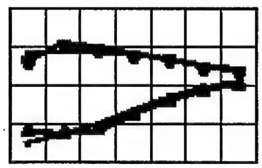


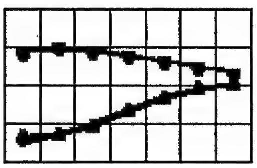


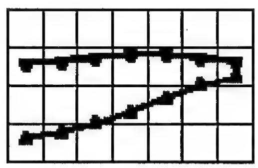


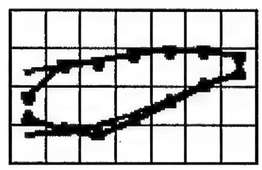






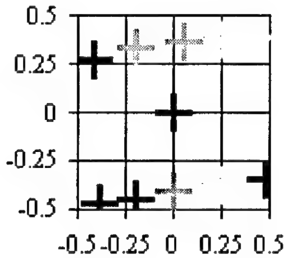


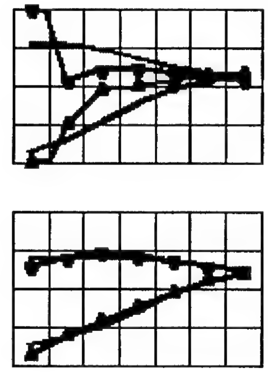


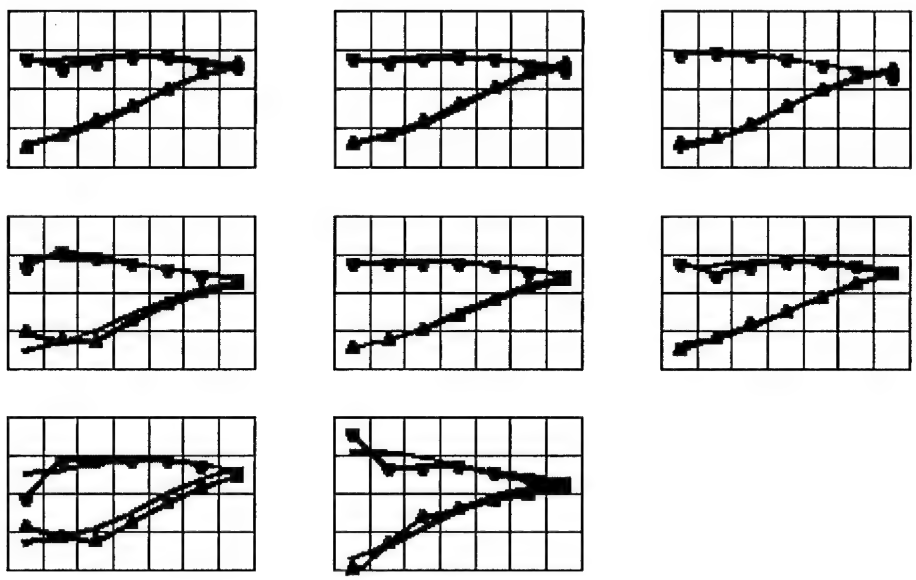


Target 2-130

Diameter : 81mm
Depth : 70
Azimuth : 0
Inclination : 0

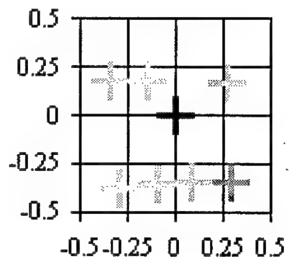


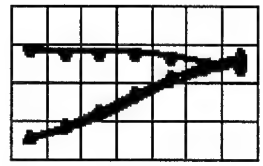


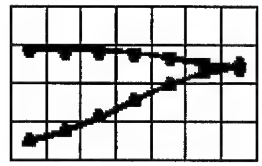


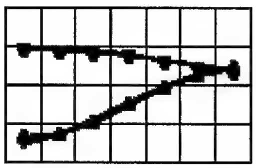
Target 2-131

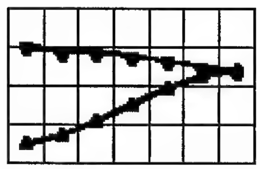
Diameter : 81mm
Depth : 25
Azimuth : 0
Inclination : 0

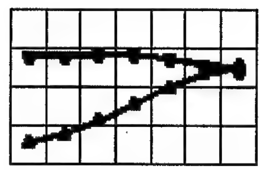


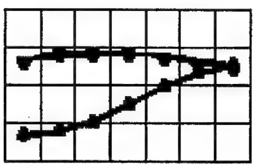


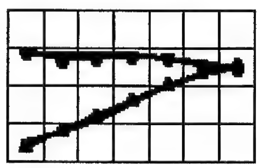






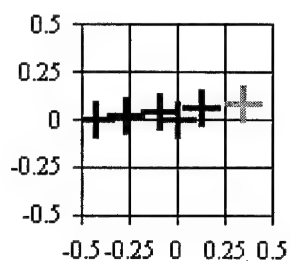


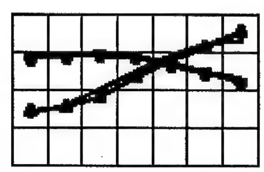


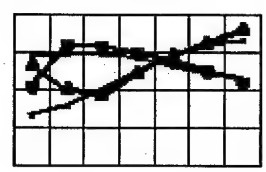


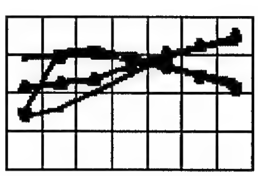
Target 2-132

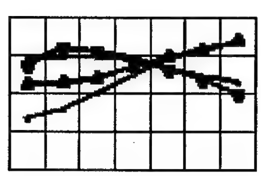
Diameter : 5.0in
Depth : 91
Azimuth : 90
Inclination : 0

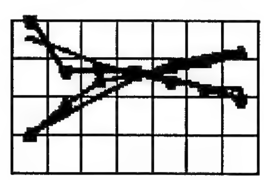






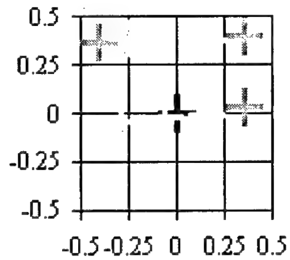


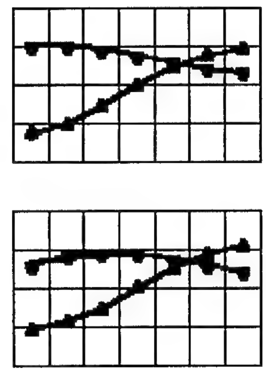


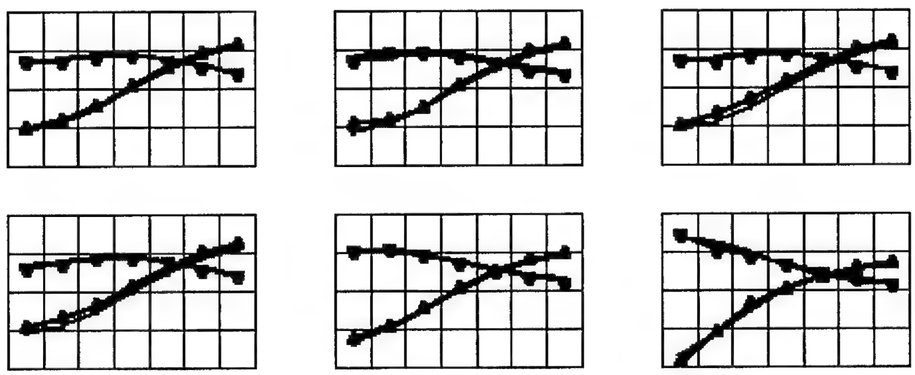


Target 2-134

Diameter : 4.2in
Depth : 40
Azimuth : 0
Inclination : 0

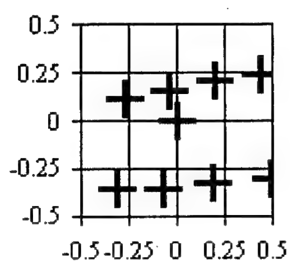


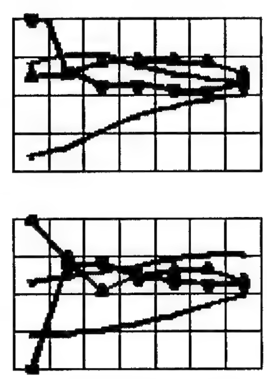


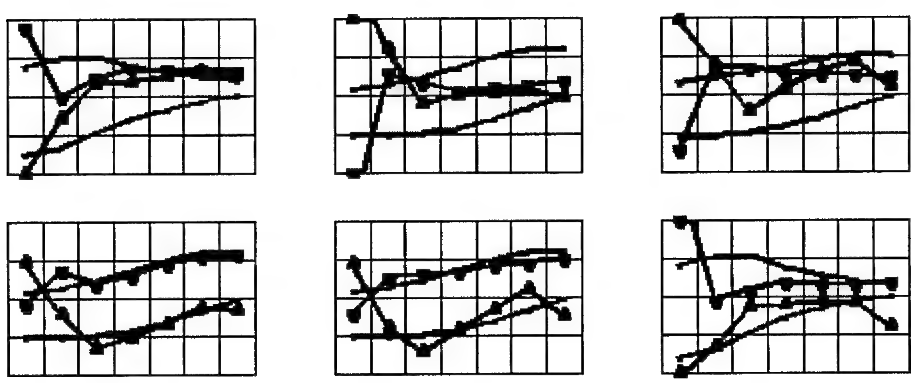


Target 2-136

Diameter : 20mm
Depth : 5
Azimuth : 120
Inclination : 10

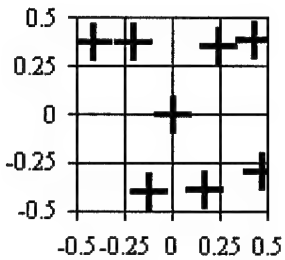


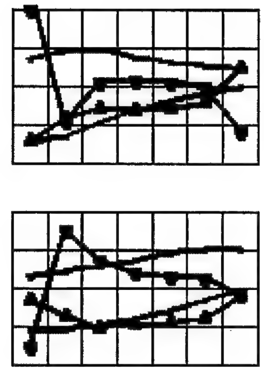


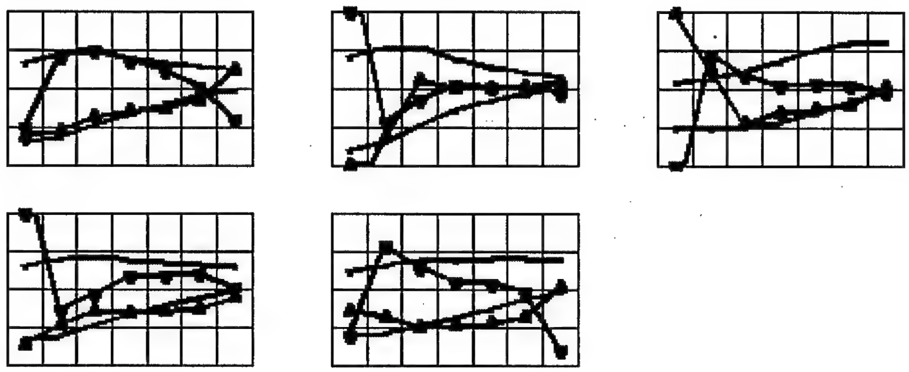


Target 2-138

Diameter : 20mm
Depth : 5
Azimuth : 275
Inclination : 15

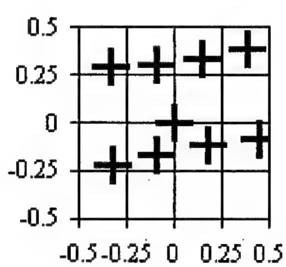


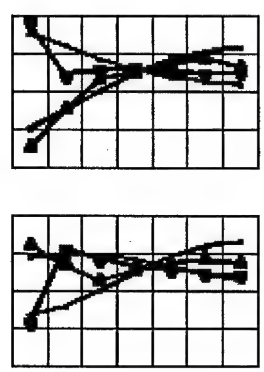


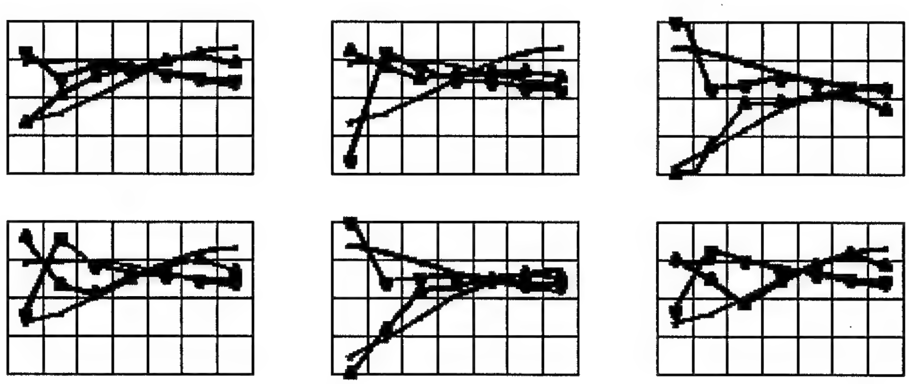


Target 2-140

Diameter : 105mm
Depth : 70
Azimuth : 330
Inclination : 10

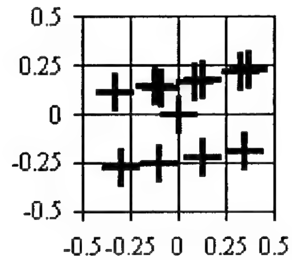


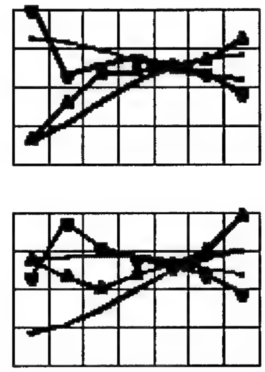


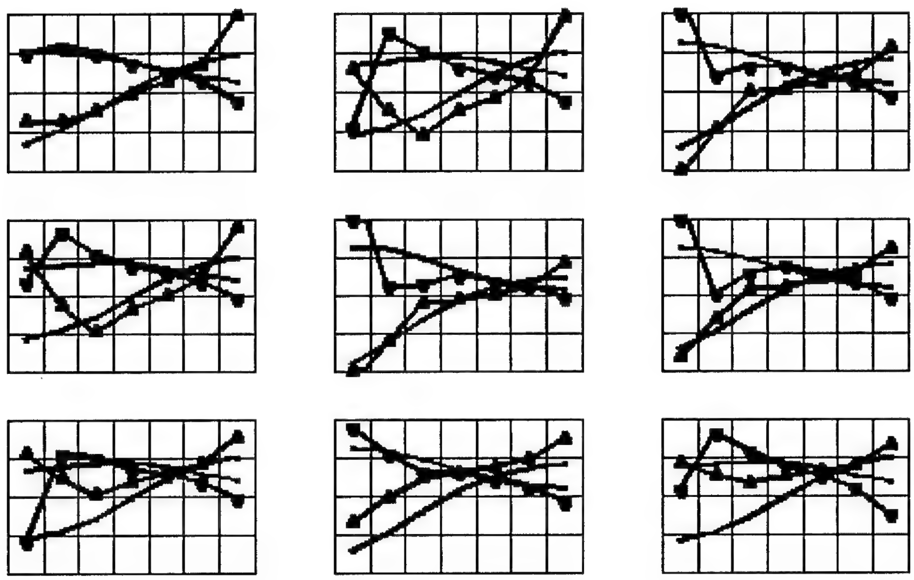


Target 2-142

Diameter : 152mm
Depth : 91
Azimuth : 300
Inclination : 45

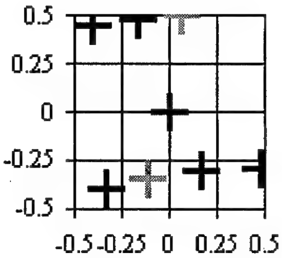


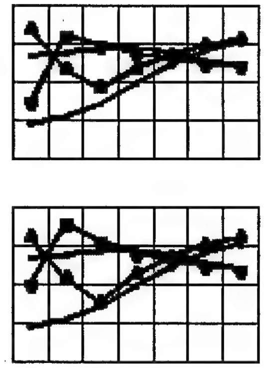


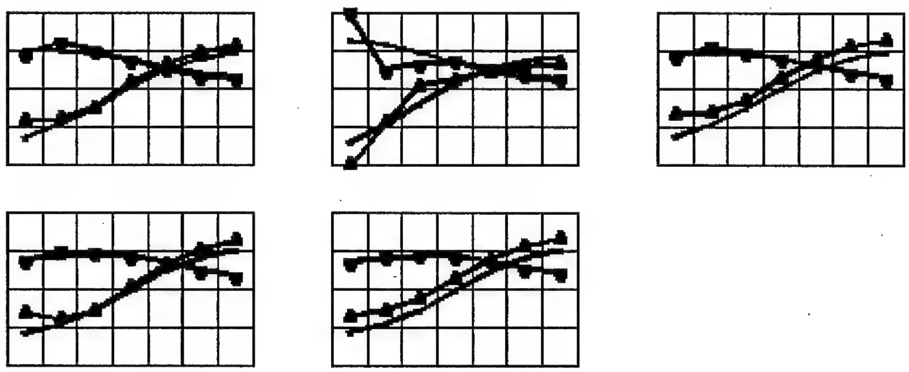


Target 2-144

Diameter : 152mm
Depth : 45
Azimuth : 50
Inclination : 30

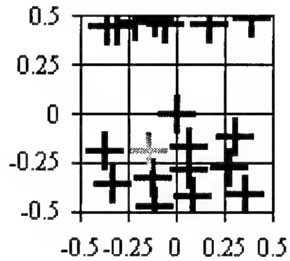


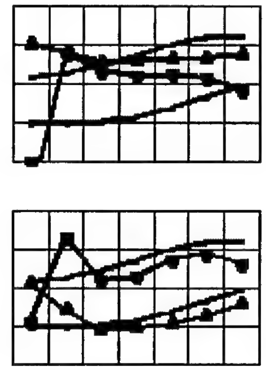


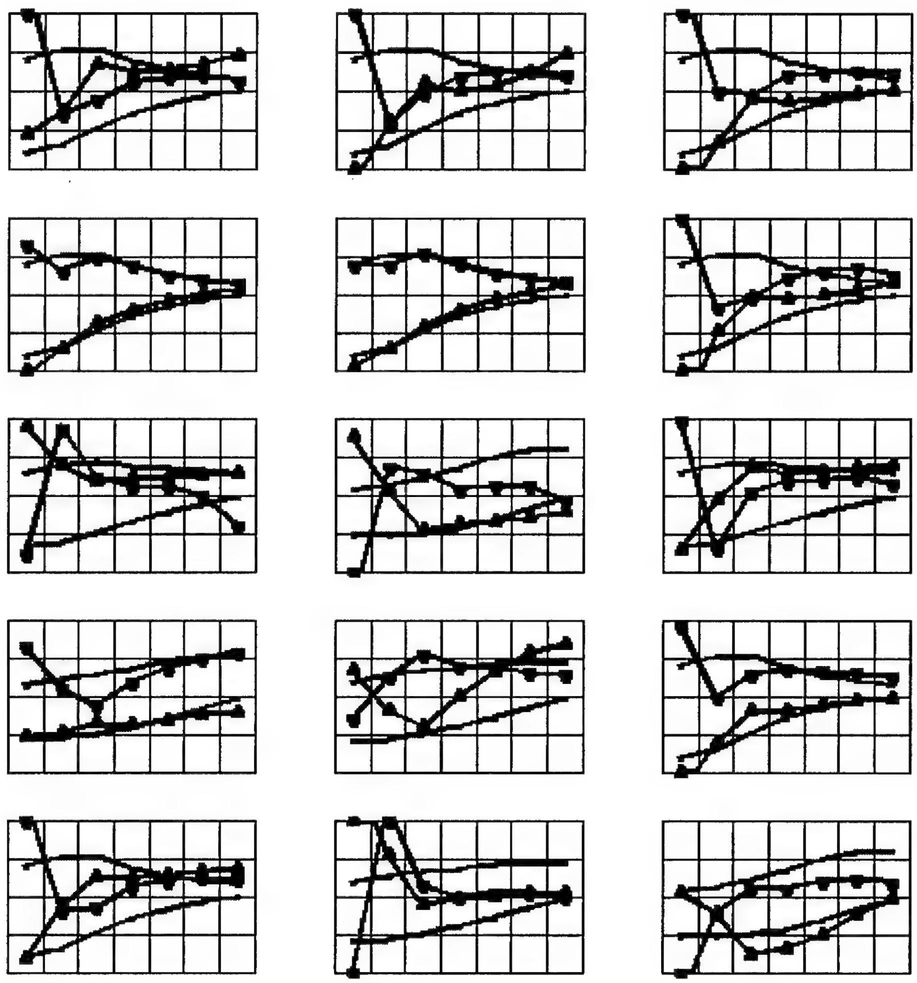


Target 2-146

Diameter : 20mm
Depth : 0
Azimuth : 0
Inclination : 90

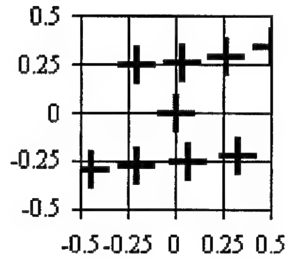


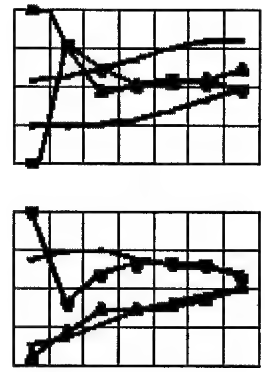


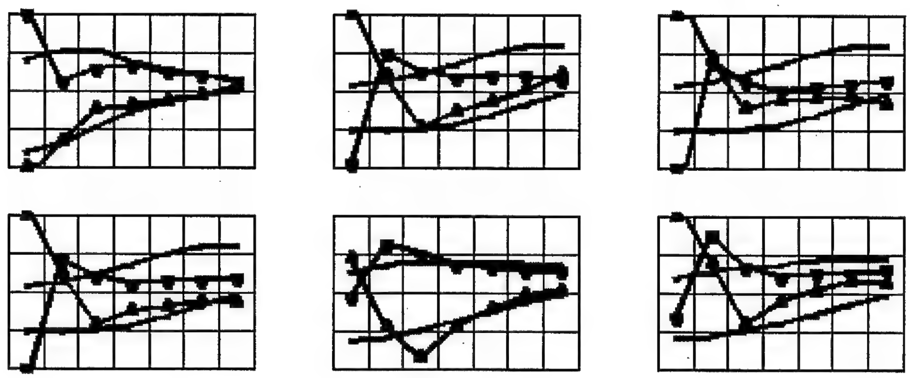


Target 2-148

Diameter : 20mm
Depth : 0
Azimuth : 0
Inclination : -90

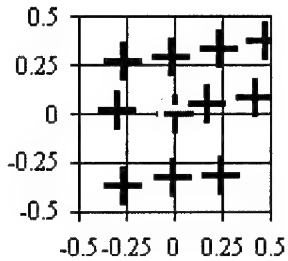


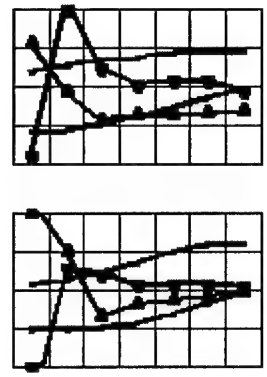


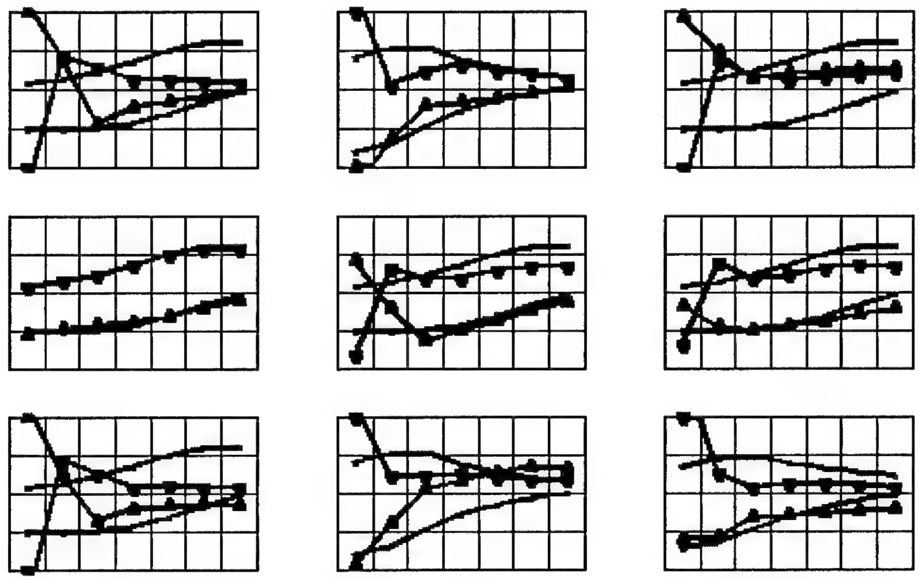


Target 2-150

Diameter : 20mm
Depth : 10
Azimuth : 0
Inclination : 0

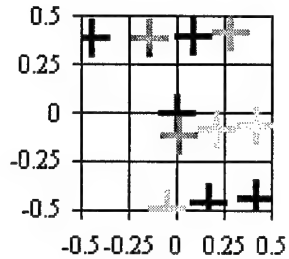


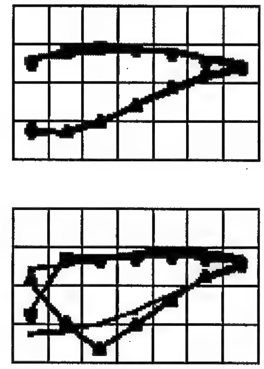


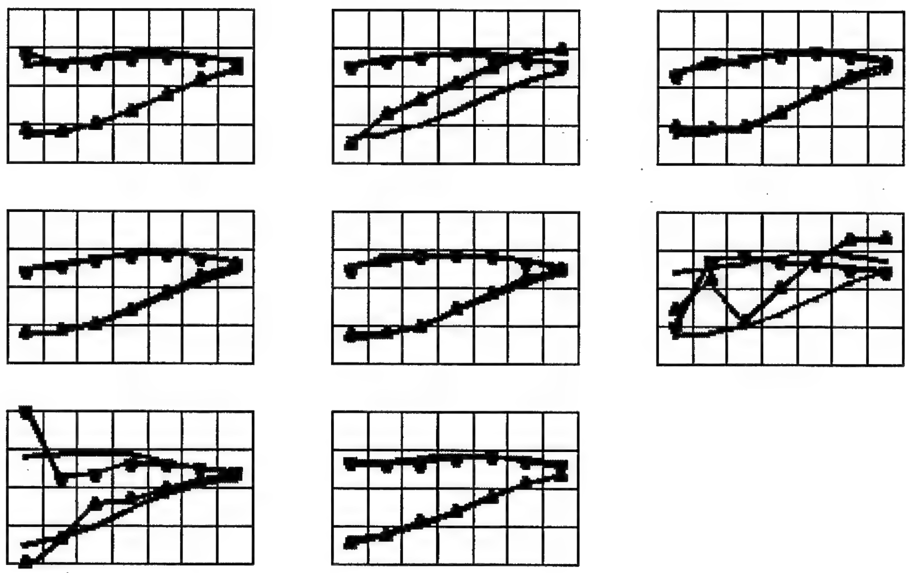


Target 2-152

Diameter : 57mm
Depth : 25
Azimuth : 90
Inclination : 0

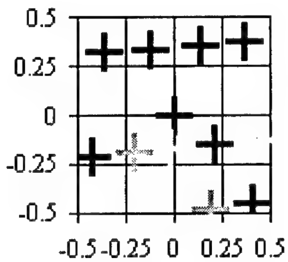


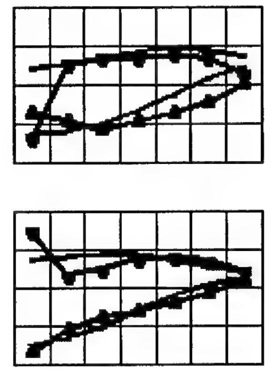


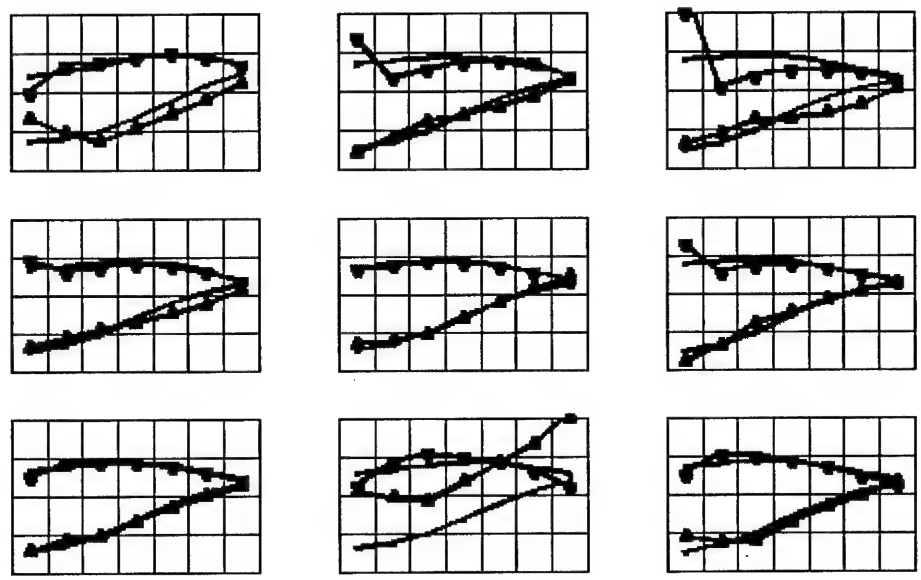


Target 2-154

Diameter : 57mm
Depth : 20
Azimuth : 180
Inclination : 45

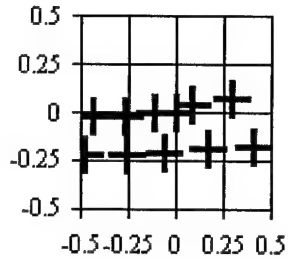


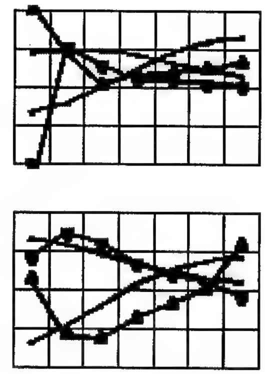


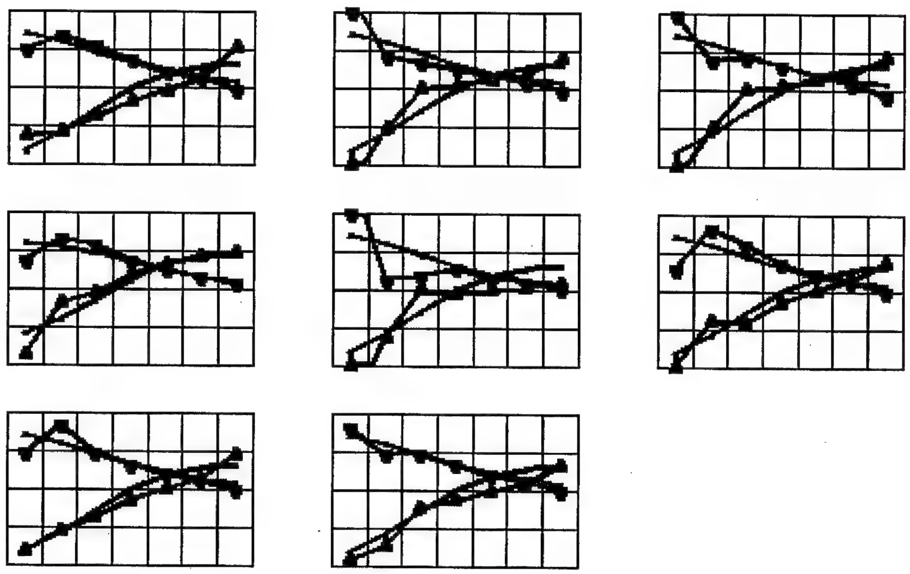


Target 2-156

Diameter : 155mm
Depth : 102
Azimuth : 0
Inclination : 90

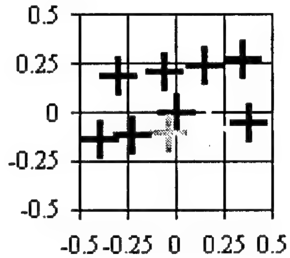


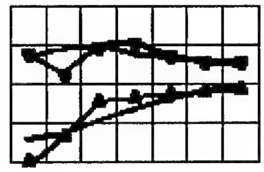


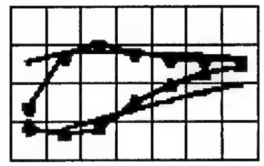


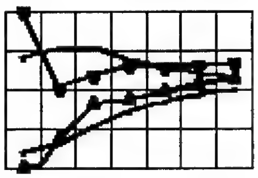
Target 2-158

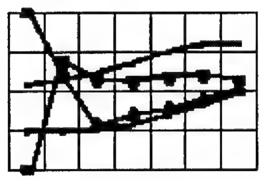
Diameter : 20mm
Depth : 10
Azimuth : 220
Inclination : 20

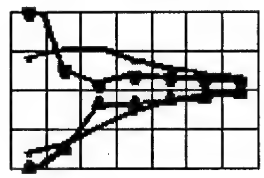


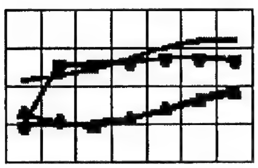


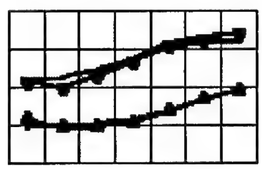


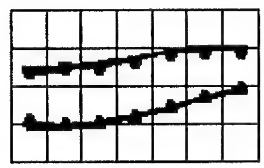


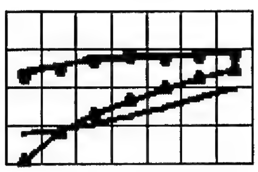






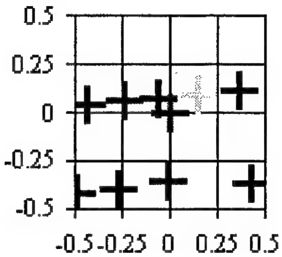


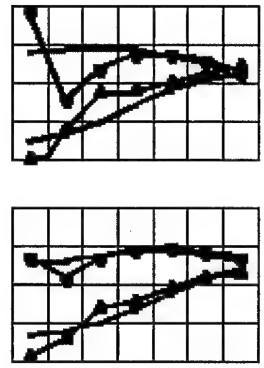


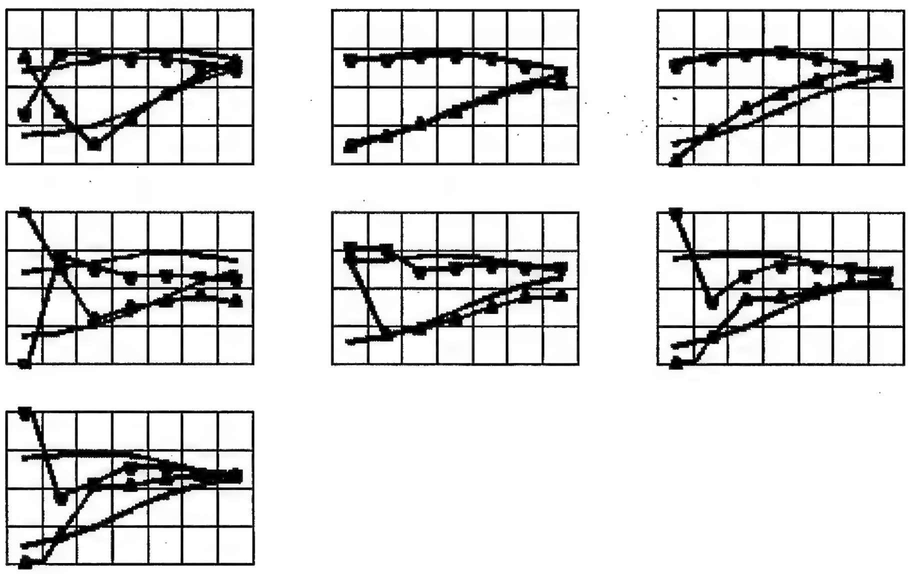


Target 2-160

Diameter : 57mm
Depth : 35
Azimuth : 270
Inclination : 40

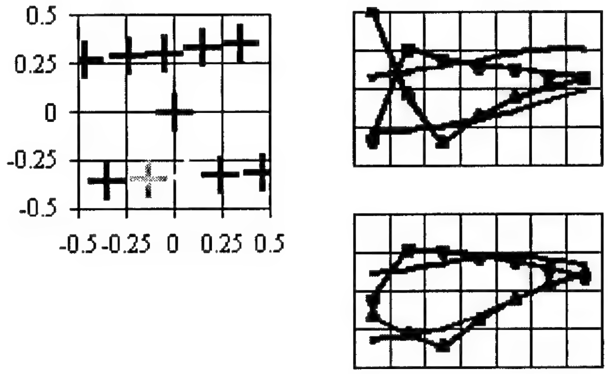


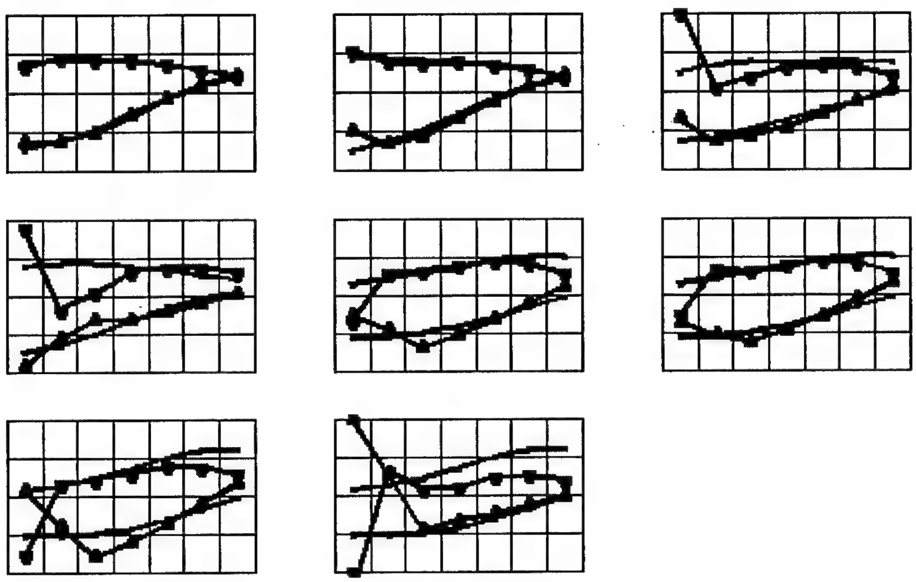




Target 2-162

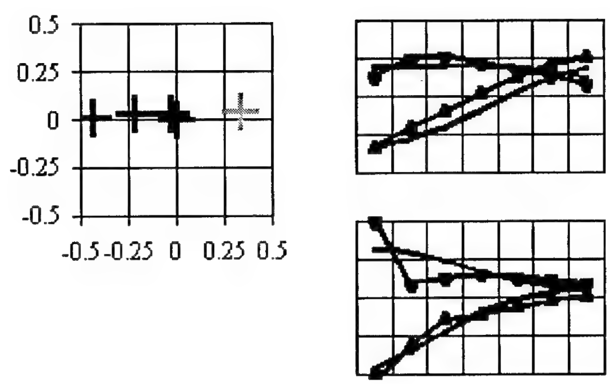
Diameter : 76mm
Depth : 50
Azimuth : 0
Inclination : 0

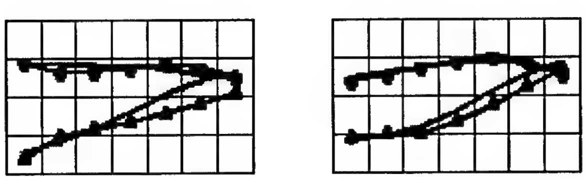




Target 2-164

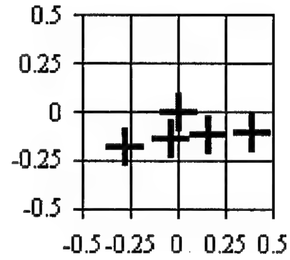
Diameter : 2.75in
Depth : 60
Azimuth : 90
Inclination : 10

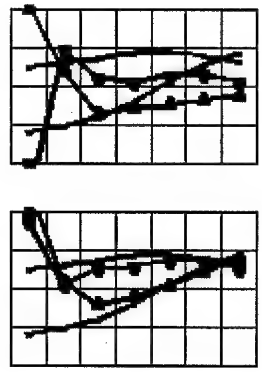


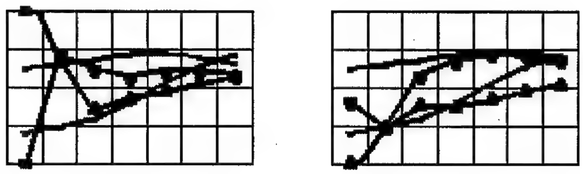


Target 2-166

Diameter : 2.75in
Depth : 75
Azimuth : 180
Inclination : 20

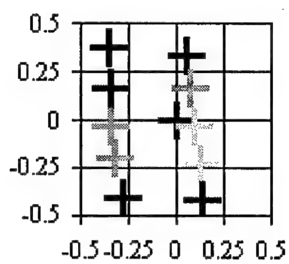


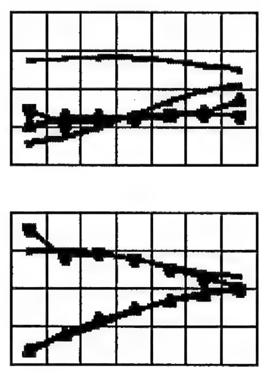


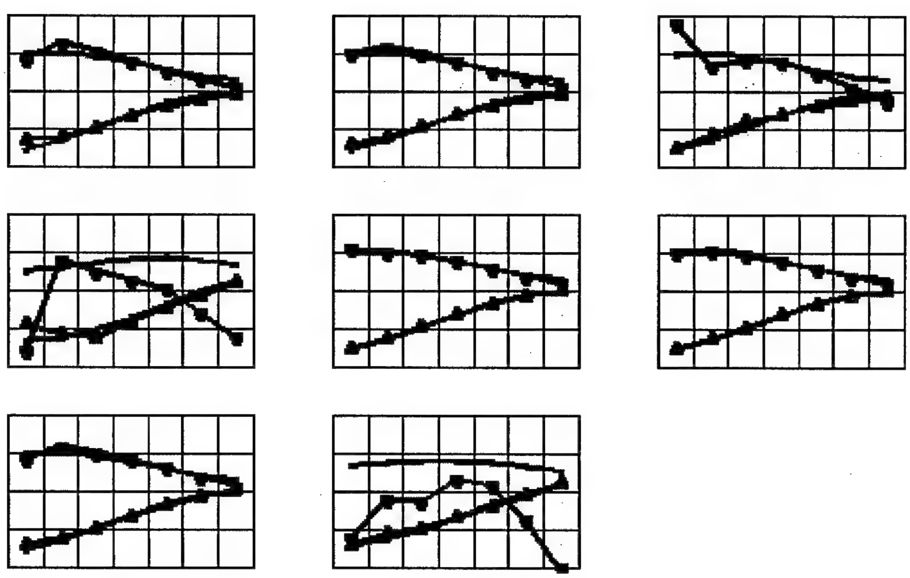


Target 3-68

Diameter : 60mm
Depth : 20
Azimuth : 0
Inclination : 90

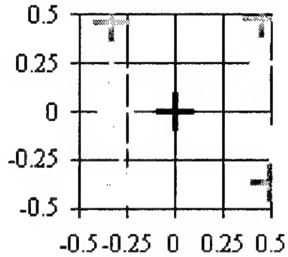


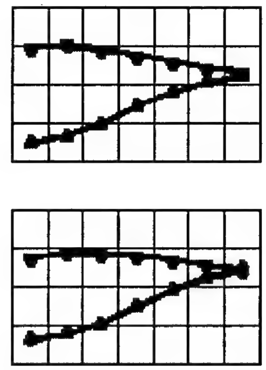


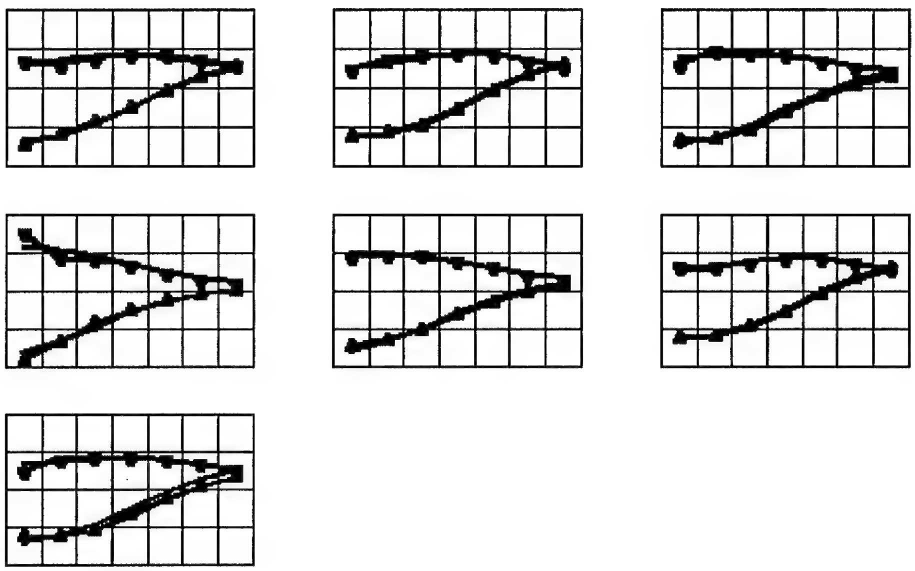


Target 3-70

Diameter : 81mm
Depth : 25
Azimuth : 0
Inclination : 0

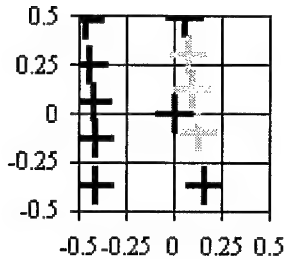


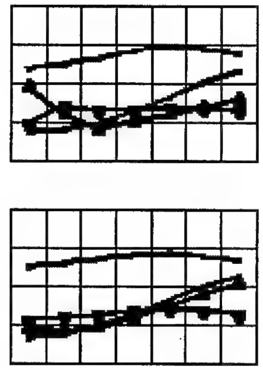


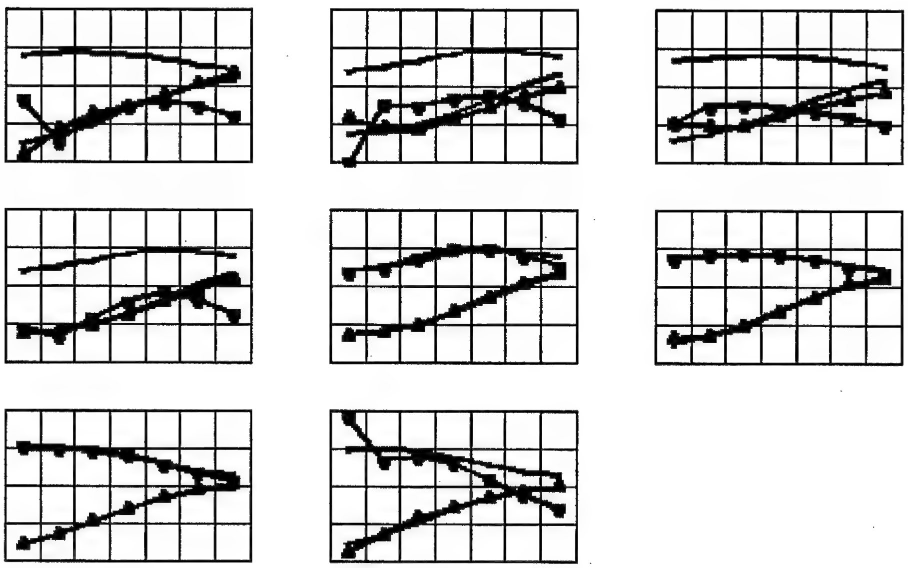


Target 3-72

Diameter : 60mm
Depth : 25
Azimuth : 45
Inclination : 30

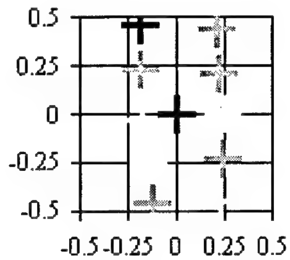


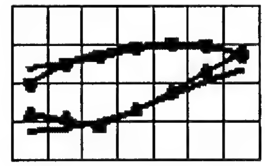


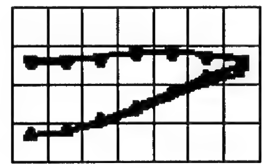


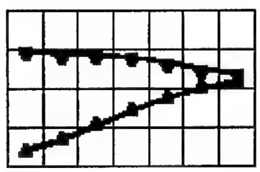
Target 3-74

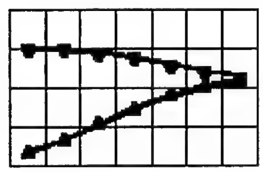
Diameter : 60mm
Depth : 30
Azimuth : 225
Inclination : 45

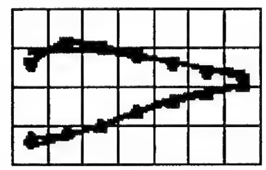


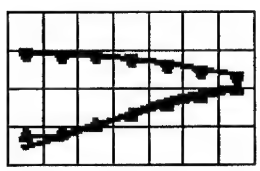


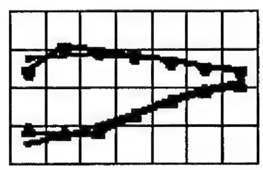


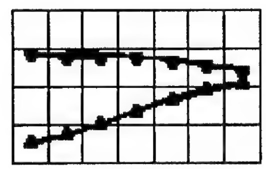


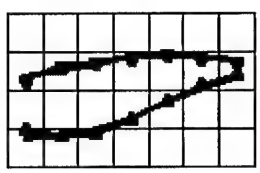


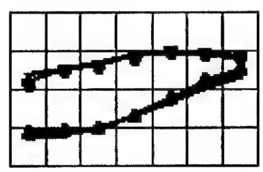






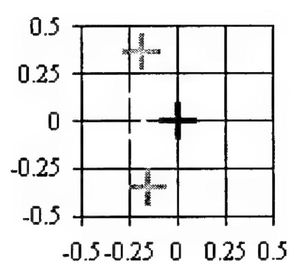


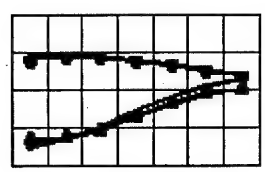


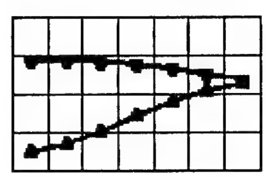


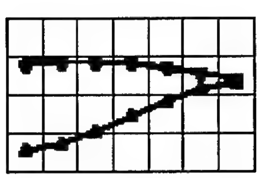
Target 3-76

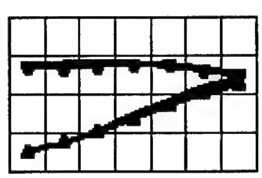
Diameter : 81mm
Depth : 20
Azimuth : 0
Inclination : -90





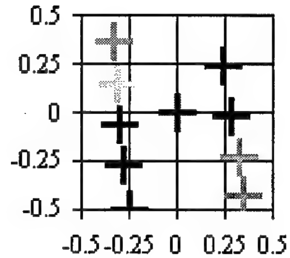


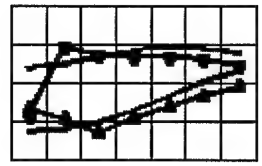


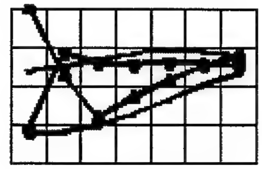


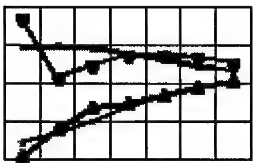
Target 3-78

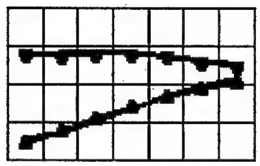
Diameter : 60mm
Depth : 35
Azimuth : 330
Inclination : 40

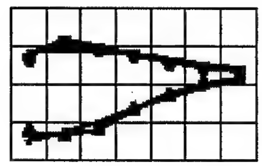


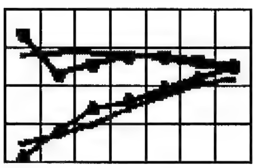


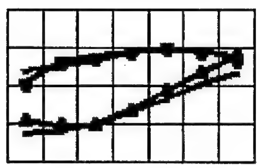


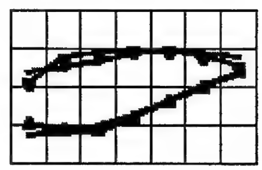


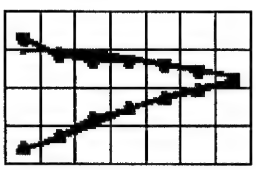






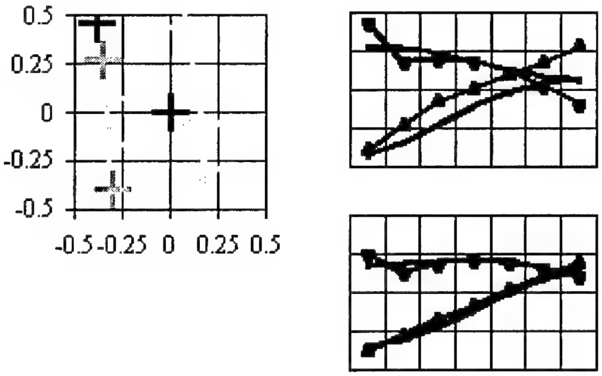


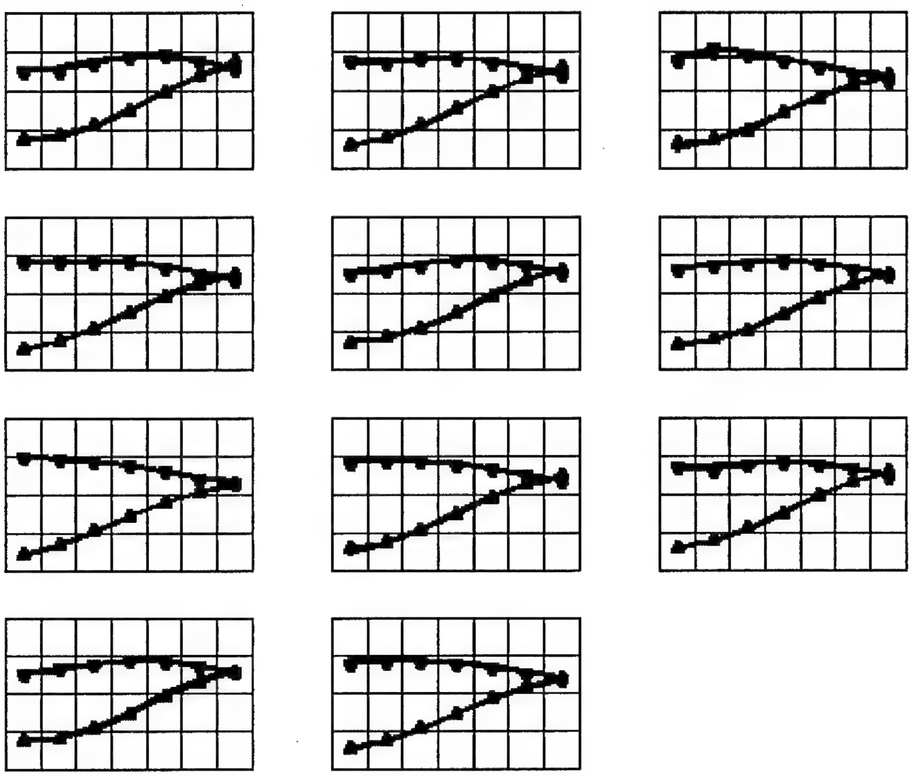




Target 3-80

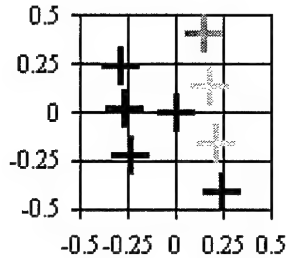
Diameter : 81mm
Depth : 25
Azimuth : 180
Inclination : 0

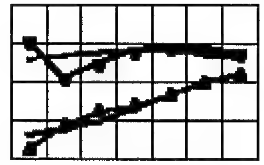


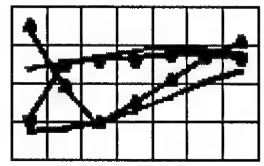


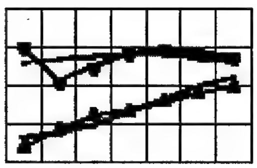
Target 3-82

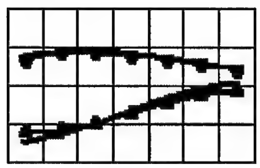
Diameter : 60mm
Depth : 20
Azimuth : 270
Inclination : 15

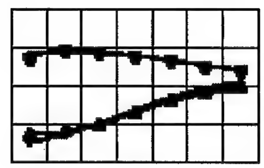


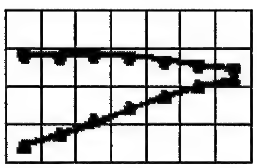


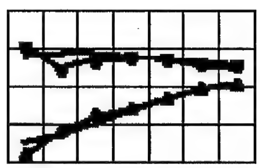






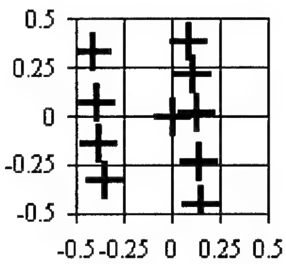


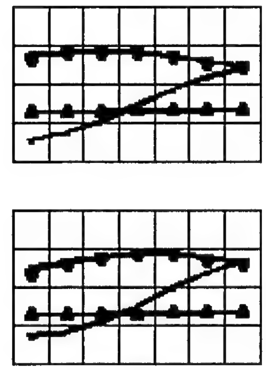


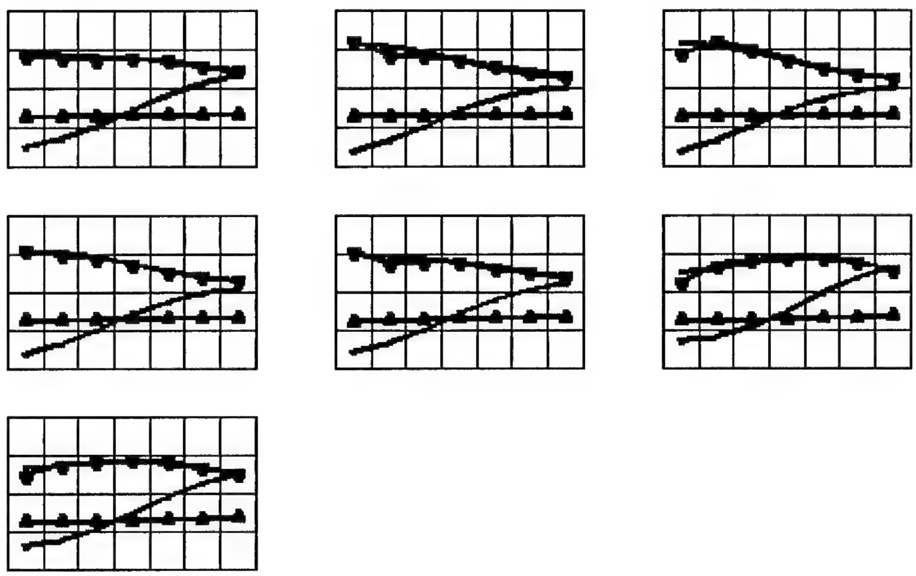


Target 3-84

Diameter : 81mm
Depth : 25
Azimuth : 0
Inclination : 0

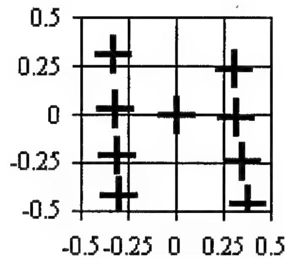


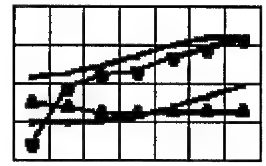


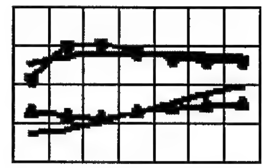


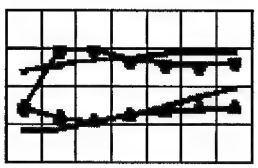
Target 3-86

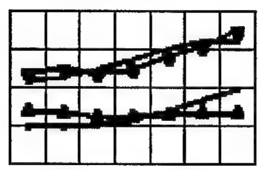
Diameter : 20mm
Depth : 1
Azimuth : 0
Inclination : 90

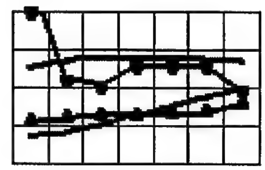


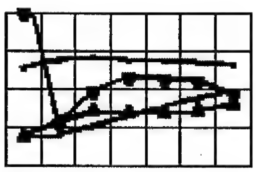


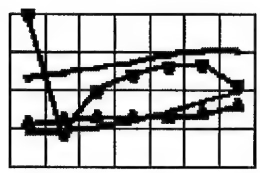


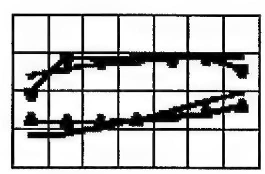






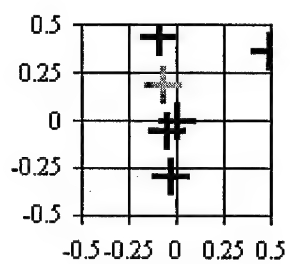


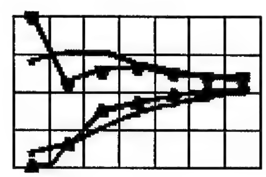


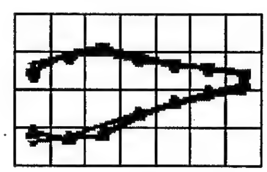


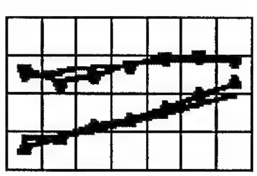
Target 3-88

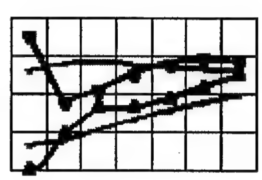
Diameter : 20mm
Depth : 1
Azimuth : 0
Inclination : 0

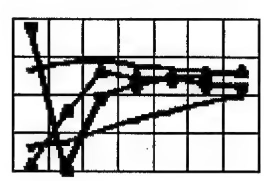






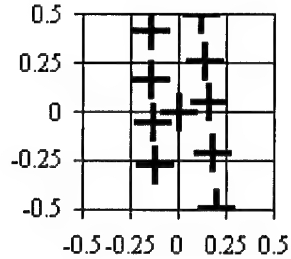


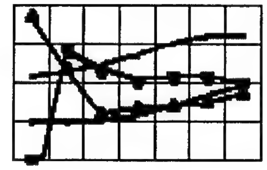


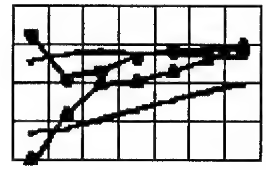


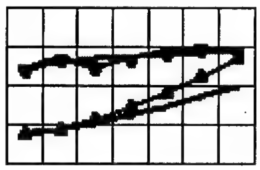
Target 3-90

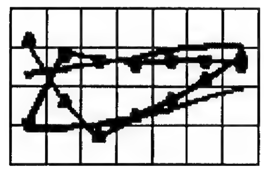
Diameter : 20mm
Depth : 15
Azimuth : 90
Inclination : 0

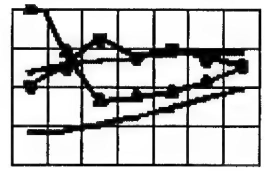


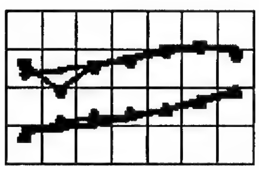


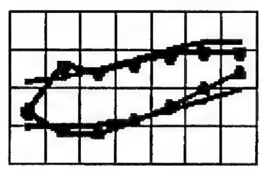


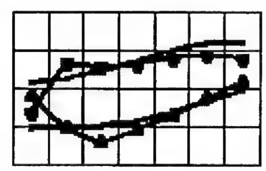


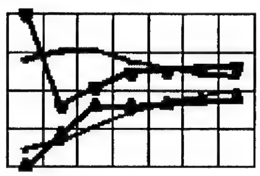






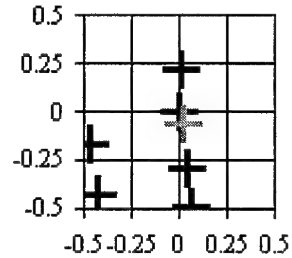


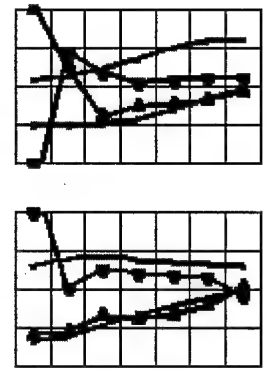


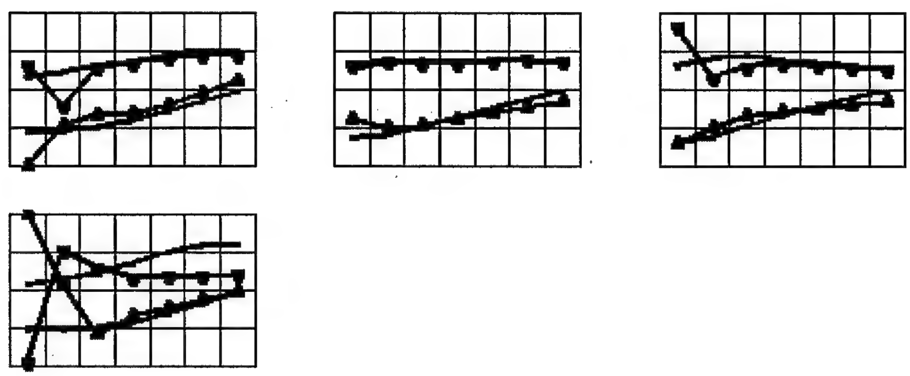


Target 3-92

Diameter : 20mm
Depth : 15
Azimuth : 120
Inclination : 30

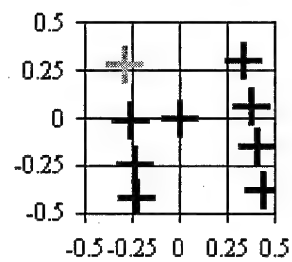


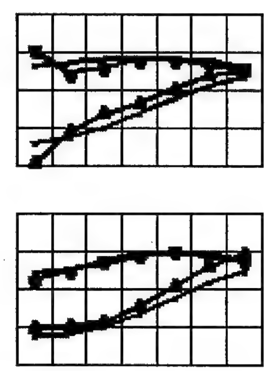


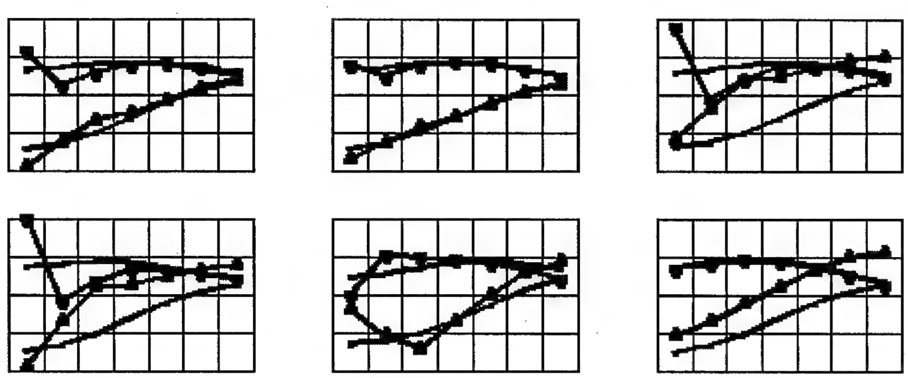


Target 3-94

Diameter : 57mm
Depth : 35
Azimuth : 330
Inclination : 0

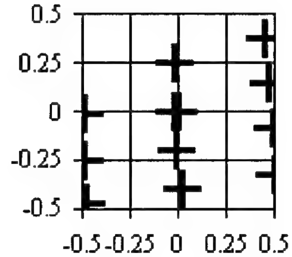


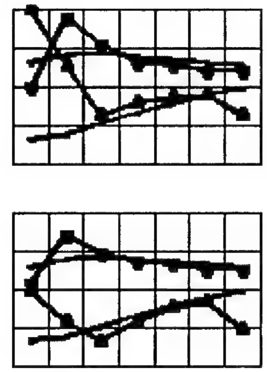


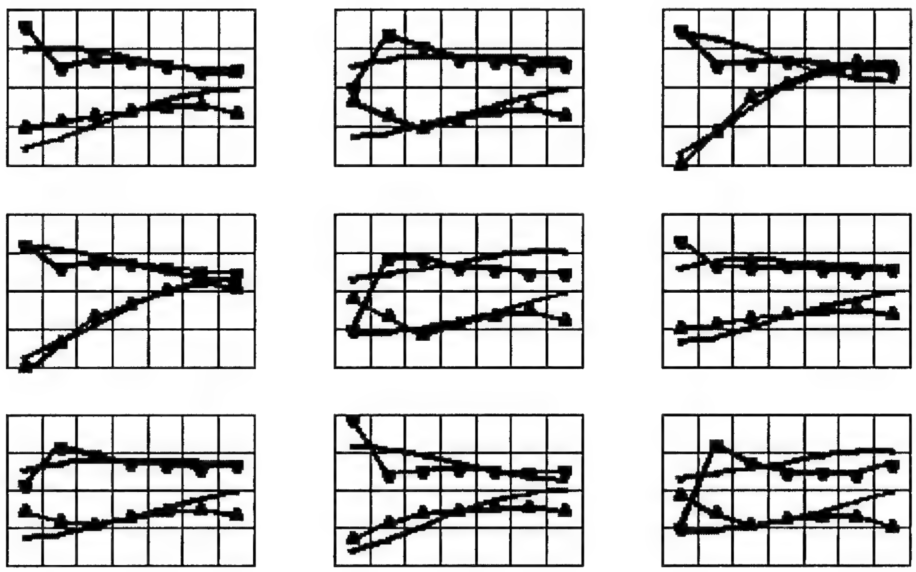


Target 3-98

Diameter : 105mm
Depth : 50
Azimuth : 0
Inclination : -45

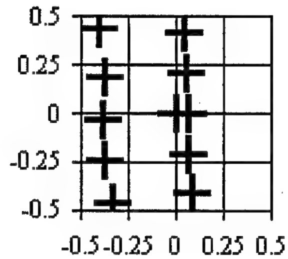


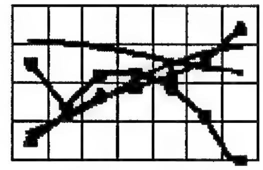


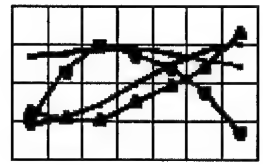


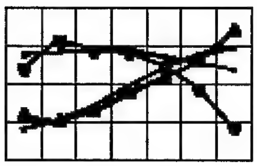
Target 3-100

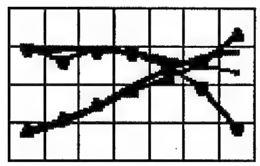
Diameter : 152mm
Depth : 91
Azimuth : 90
Inclination : 35

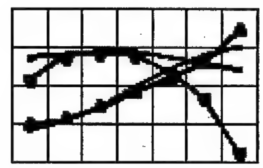


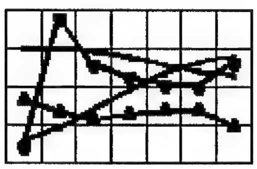


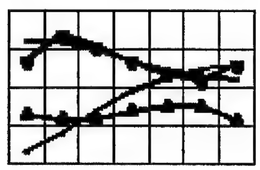


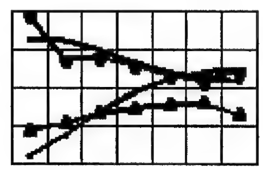


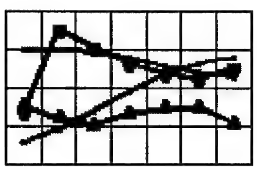


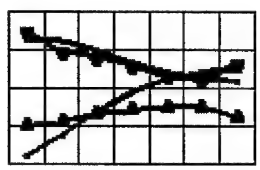






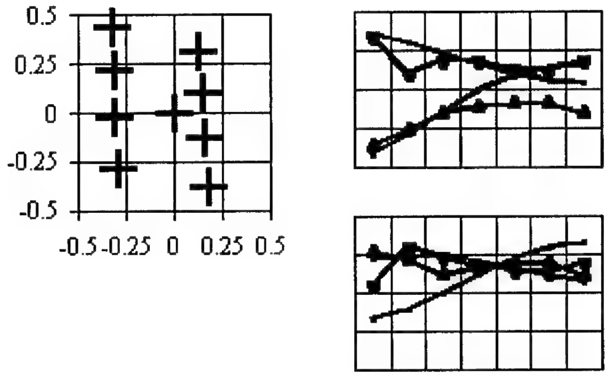


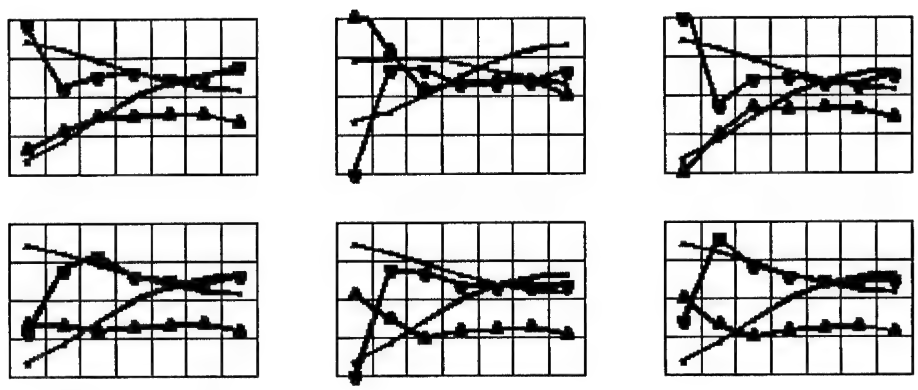




Target 3-102

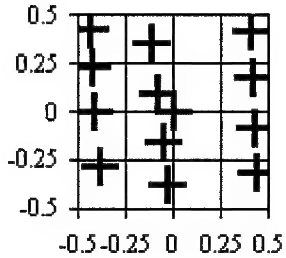
Diameter : 155mm
Depth : 120
Azimuth : 30
Inclination : 20

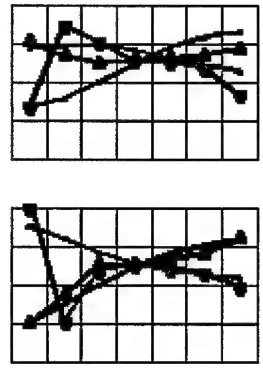


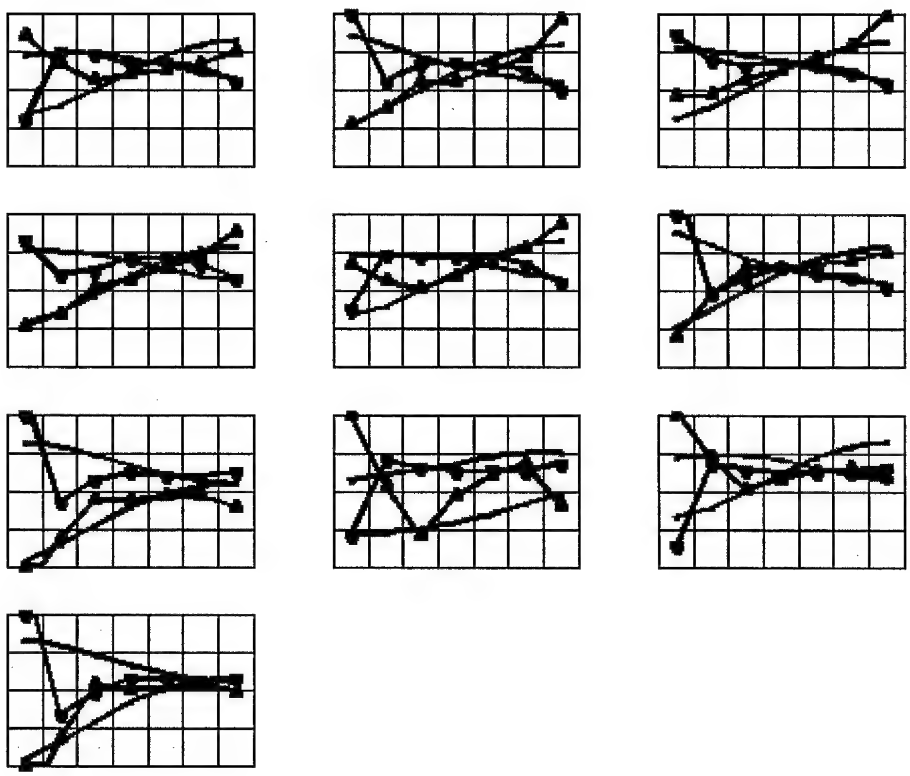


Target 3-104

Diameter : 76mm
Depth : 76
Azimuth : 0
Inclination : 0

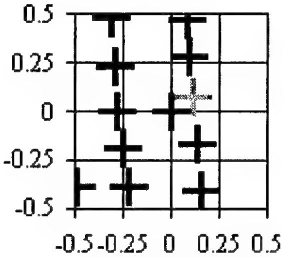


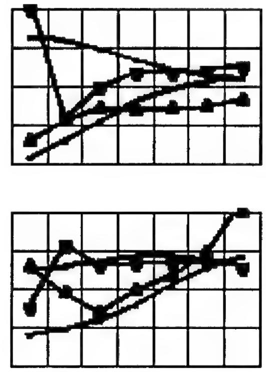


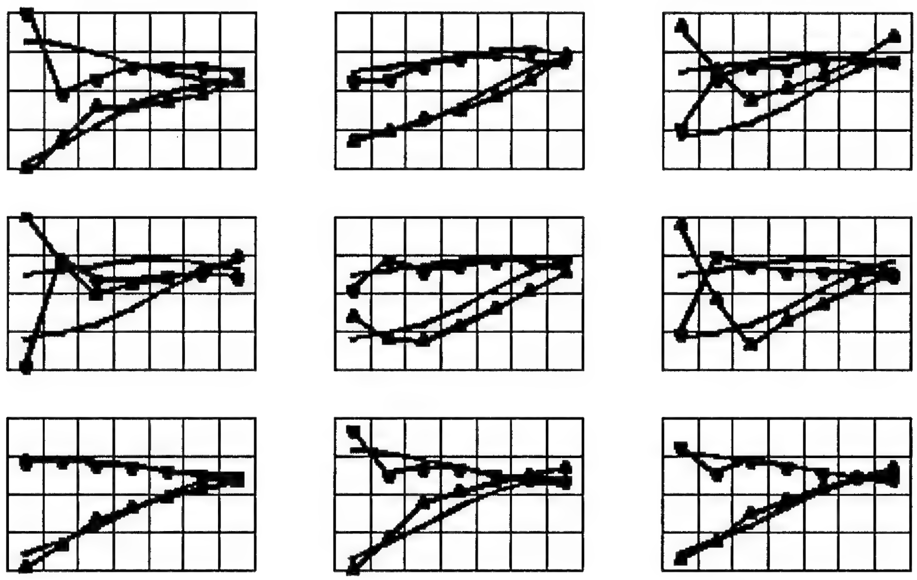


Target 3-106

Diameter : 2.75in
Depth : 50
Azimuth : 120
Inclination : 30







Appendix C
Code Listings

Gem-3 Analysis Program

Main.frm

```
Private Sub Check1_Click(Index As Integer)

   If Check1(Index).Value = 1 Then SelFreq(Index + 1) = True
   If Check1(Index).Value = 0 Then SelFreq(Index + 1) = False

   'Re-Calculate sums for only frequencies currently selected
   For i = 1 To NumPoints
      totali = 0
      totalq = 0
      For j = 1 To 7
         If SelFreq(j) Then totali = totali + Abs(InPhase(i, j))
         If SelFreq(j) Then totalq = totalq + Abs(Quadrature(i, j))
      Next j
      Itotal(i) = totali
      Qtotal(i) = totalq
   Next i
   For i = 1 To NumCal
      CalQtotal(i) = 0#
      CalItotal(i) = 0#
      For j = 1 To 7
         If SelFreq(j) Then CalQtotal(i) = CalQtotal(i) + Abs(CalQuadrature(i, j))
         If SelFreq(j) Then CalItotal(i) = CalItotal(i) + Abs(CalInPhase(i, j))
      Next j
   Next i
   temp = List2.ListIndex
   UpdateList2
   List2.ListIndex = temp
```

```
    List2_Click

End Sub

Private Sub Check2_Click()

   ShowBest = Not ShowBest
   temp = List2.ListIndex
   UpdateList2
   List2.ListIndex = temp
   List2_Click

End Sub

Private Sub Classify_Click()

   Open "matches.txt" For Output As #2
   Threshold = Thresh_text.Text

   For j = 1 To 12
      For k = 1 To 12
         Confusion(j, k) = 0
      Next k
   Next j

   For m = 1 To NumItems
      Max = 0
      ItemMinDist(m) = 999999#
      For j = ItemStart(m) To ItemEnd(m)
         If (Qtotal(j) + Itotal(j) > Max) Then
            Max = Qtotal(j) + Itotal(j)
            i = j
         End If
         If (Tdist(j) < ItemMinDist(m)) Then ItemMinDist(m) = Tdist(j)
      Next j
      FindCombinedMatches (i)
      Print #2, Format(TargetId(i), "@@@@@ "), Format(Qtotal(i) + Itotal(i),
"00000  ") + _
            Format(Tdist(i), "0.000")
      For j = 1 To 8
         Print #2, CmatchUxo(j) & Space(25 - Len(CmatchUxo(j))) &
Format(CmatchError(j), "0.0000  ")
      Next j
      found = 0
      For k = 1 To TgtNum
         If TargetId(i) = TgtId(k) Then
            For j = 1 To 11
               If TgtType(k) = UXO(j) Then Row = j
               If InStr(CmatchUxo(1), UXO(j)) > 0 Then
```

```
                col = j
                If CmatchError(1) > Threshold Then col = 12
              End If
            Next j
            found = 1
          End If
        Next k
          If found = 1 Then
            Confusion(Row, col) = Confusion(Row, col) + 1
          Else
            For j = 1 To 11
              If InStr(CmatchUxo(1), UXO(j)) > 0 Then
                col = j
                If CmatchError(1) > Threshold Then col = 12
              End If
            Next j
            Confusion(12, col) = Confusion(12, col) + 1
          End If
      Next m

      Print #2,
      Print #2,
      linestr = "  UXO   " + Format(UXO(1), "@@@@@@ ") + Format(UXO(2),
"@@@@@@ ") + Format(UXO(3), "@@@@@@ ") + _
           Format(UXO(4), "@@@@@@ ") + Format(UXO(5), "@@@@@@ ") +
Format(UXO(6), "@@@@@@ ") + _
           Format(UXO(7), "@@@@@@ ") + Format(UXO(8), "@@@@@@ ") +
Format(UXO(9), "@@@@@@ ") + _
           Format(UXO(10), "@@@@@@ ") + Format(UXO(11), "@@@@@@ ") +
"  FA  "
      Print #2, linestr
      For j = 1 To 12
        linestr = Format(UXO(j), " @@@@@@@") + Format(Confusion(1, j), "   0   ")
+ Format(Confusion(2, j), "   0   ") + _
             Format(Confusion(3, j), "   0   ") + Format(Confusion(4, j), "   0   ") +
Format(Confusion(5, j), "   0   ") + _
             Format(Confusion(6, j), "   0   ") + Format(Confusion(7, j), "   0   ") +
Format(Confusion(8, j), "   0   ") + _
             Format(Confusion(9, j), "   0   ") + Format(Confusion(10, j), "   0   ") +
Format(Confusion(11, j), "   0   ") + _
             Format(Confusion(12, j), "   0   ")
        Print #2, linestr
       Next j

      Print #2,
      Print #2,
      For m = 1 To NumItems
        Print #2, ItemId(m), ItemEnd(m) - ItemStart(m) + 1, Format(ItemMinDist(m),
"0.0000")
```

```
   Next m

   Close #2
   ans = MsgBox("Done", vbOKOnly)
End Sub

Private Sub List3_Click()

   j = List3.ListIndex + 1
   If j <= 0 Then Exit Sub
   For i = 1 To NumItems
      If TargetId(ItemStart(i)) = TgtId(j) Then Exit For
   Next i
   If i <= NumItems Then
      k = i
      List1.ListIndex = k - 1
   Else
      ans = MsgBox("Target not found", vbOKOnly)
      Exit Sub
   End If

   List1_Click

End Sub

Private Sub MatchAll_old_Click()

   Open "allmatches.txt" For Output As #2

   For i = 1 To NumPoints
      FindCombinedMatches (i)
      Print #2, Format(TargetId(i), "@@@@@ "), Format(Qtotal(i) + Itotal(i),
"00000  ") + _
              Format(Tdist(i), "0.000")
      For j = 1 To 8
         Print #2, CmatchUxo(j) & Space(25 - Len(CmatchUxo(j))) &
Format(CmatchError(j), "0.0000  ")
      Next j
    Next i

   Close #2
   ans = MsgBox("Done", vbOKOnly)

End Sub

Private Sub List1_Click()

Dim info As String
```

```
    UpdateList2
    List2.ListIndex = 0
    List2_Click

    j = List1.ListIndex + 1
    For i = 1 To TgtNum
        If TargetId(ItemStart(j)) = TgtId(i) Then Exit For
    Next i
    If i <= TgtNum Then
        k = i
        List3.ListIndex = k - 1
    Else
        List3.ListIndex = -1
    End If

    plotloc

End Sub

Private Sub List2_Click()

    NextPlot = ItemStart(NextItem) + List2.ListIndex
    plotloc
    plotiq

End Sub
Private Sub UpdateList2()

    List2.Clear
    k = List1.ListIndex + 1
    NextItem = k
    For i = ItemStart(k) To ItemEnd(k)
        FindCombinedMatches (i)
        BestMatchUxo(i) = CmatchUxo(1)
        BestMatchError(i) = CmatchError(1)
        info = Format(TargetId(i), "@@@@@ ") + Format(Qtotal(i) + Itotal(i),
"00000 ") + _
            Format(Tdist(i), "0.000   ")
        For j = 1 To 8
            info = info + CmatchUxo(j) & Space(19 - Len(CmatchUxo(j))) &
Format(CmatchError(j), "0.0000   ")
            If (Not ShowBest) And List3.ListIndex >= 0 Then
                If InStr(CmatchUxo(j), TgtType(List3.ListIndex + 1)) > 0 Then
                    BestMatchUxo(i) = CmatchUxo(j)
                    BestMatchError(i) = CmatchError(j)
                End If
            End If
        Next j
```

```
    List2.AddItem info
  Next i

End Sub

Private Sub Exit_Click()

  Unload Me

End Sub

Private Sub Form_Load()

Dim linestr As String

  UXO(1) = "20mm"
  UXO(2) = "57mm"
  UXO(3) = "60mm"
  UXO(4) = "2.75in"
  UXO(5) = "76mm"
  UXO(6) = "81mm"
  UXO(7) = "105mm"
  UXO(8) = "4.2in"
  UXO(9) = "5.0in"
  UXO(10) = "152mm"
  UXO(11) = "155mm"
  UXO(12) = "Non-Ord"
  NextPlot = 0
  NextTgt = 0
  For i = 1 To 7
    SelFreq(i) = True
  Next i
  Threshold = 0.1
  Thresh_text.Text = Threshold
  ShowBest = True

  ReadCal
  CalStats
  NewArea (1)

End Sub

Public Sub NewArea(area As Integer)

  List3.Clear
  ReadTargets (area)
  For i = 1 To TgtNum
    linestr = Format(TgtId(i), "@@@@@ ") + Format(TgtType(i), "@@@@@@
") + Format(TgtNorthing(i), "#######.000  ") + _
```

```
            Format(TgtEasting(i), "######.000  ") + Format(TgtDepth(i), "000  ")
+ Format(TgtAzimuth(i), "000  ") + _
            Format(TgtInclination(i), "000")
      List3.AddItem linestr
   Next i

   List1.Clear
   ReadArea (area)
   For i = 1 To NumItems
      List1.AddItem ItemId(i)
   Next i

   List1.ListIndex = 0
   List1_Click
   PrintComparison

End Sub
Public Sub CalStats()

   For i = 1 To NumCal
      CalQtotal(i) = 0#
      CalItotal(i) = 0#
      For j = 1 To 7
         CalQtotal(i) = CalQtotal(i) + Abs(CalQuadrature(i, j))
         CalItotal(i) = CalItotal(i) + Abs(CalInPhase(i, j))
      Next j
      qsf = 1000# / CalQtotal(i)
      isf = 1000# / CalItotal(i)
      For j = 1 To 7
         CalQuadrature(i, j) = CalQuadrature(i, j) * qsf
         CalInPhase(i, j) = CalInPhase(i, j) * isf
      Next j
      CalQtotal(i) = 1000
      CalItotal(i) = 1000

      For j = 1 To 7
         If CalInPhase(i, j) >= 0# Then Exit For
      Next j
      If j = 1 Then
         IZero(i) = 0#
      ElseIf j = 8 Then
         IZero(i) = 8#
      Else
         diff1 = CalInPhase(i, j) - CalInPhase(i, j - 1)
         diff2 = -CalInPhase(i, j - 1)
         IZero(i) = j - 1 + (diff2 / diff1)
      End If
   Next i
End Sub
```

```
Public Sub FindCombinedMatches(i As Integer)

  Dim iScalefactor As Double
  Dim qScalefactor As Double
  Dim NormI As Double
  Dim NormQ As Double

  For j = 1 To 10
    CmatchUxo(j) = ""
    CmatchError(j) = 9999999999#
  Next j

  For k = 1 To NumCal Step 37
    minerr = 9999999#
    For m = k To k + 36
      iScalefactor = CalItotal(m) / Itotal(i)
      qScalefactor = CalQtotal(m) / Qtotal(i)
      idiff = 0#
      qdiff = 0#
      nfreq = 0
      For j = 1 To 7
        If SelFreq(j) Then
          NormI = InPhase(i, j) * iScalefactor
          idiff = idiff + (NormI - CalInPhase(m, j)) ^ 2
          NormQ = Quadrature(i, j) * qScalefactor
          qdiff = qdiff + (NormQ - CalQuadrature(m, j)) ^ 2
          nfreq = nfreq + 1
        End If
      Next j
      ierror = Sqr(idiff / nfreq) / CalItotal(m)
      qerror = Sqr(qdiff / nfreq) / CalQtotal(m)
      If (ierror + qerror) < minerr Then
        minerr = ierror + qerror
        kk = m
      End If
    Next m
    For j = 8 To 1 Step -1
      If minerr > CmatchError(j) Then Exit For
    Next j
    If j < 8 Then
      For jj = 8 To j + 2 Step -1
        CmatchUxo(jj) = CmatchUxo(jj - 1)
        CmatchError(jj) = CmatchError(jj - 1)
      Next jj
      CmatchUxo(j + 1) = UxoType(kk)
      CmatchError(j + 1) = minerr
    End If
```

```
    Next k

End Sub
Private Sub MatchAll_Click()

    Open "allmatches.txt" For Output As #2

    For i = 1 To TgtNum
        prtstr1 = Format(TgtId(i), "@@@@ ") + Format(TgtType(i), "@@@@@@ ")
        prtstr1 = prtstr1 + Format(TgtDepth(i), "##0 ") + Format(TgtInclination(i), "##0
")
        For ii = ItemStart(i) To ItemEnd(i)
            FindCombinedMatches (ii)
            For j = 1 To 8
                If Mid(CmatchUxo(j), 1, InStr(CmatchUxo(j), ",") - 1) = TgtType(i) Then
                    prtstr1 = prtstr1 + Format(CmatchError(j), "0.0000  ")
                End If
            Next j
        Next ii
        Print #2, prtstr1
    Next i

    Close #2
    ans = MsgBox("Done", vbOKOnly)

End Sub

Sub PrintComparison()

    Dim NormI(1 To 7) As Double
    Dim NormQ(1 To 7) As Double

    Open "tgt_err.txt" For Output As #2
'   Open "tgt_mag.txt" For Output As #3

    For i = 1 To TgtNum
'       prtstr1 = Format(TgtId(i), "@@@@ ") + Format(TgtType(i), "@@@@@@ ")
'       prtstr1 = prtstr1 + Format(TgtDepth(i), "##0 ") + Format(TgtInclination(i), "##0
")
'       prtstr2 = Format(TgtId(i), "@@@@ ") + Format(TgtType(i), "@@@@@@ ")
'       prtstr2 = prtstr2 + Format(TgtDepth(i), "##0 ") + Format(TgtInclination(i), "##0
")
        calmatch = 0
        For j = 19 To NumCal Step 37
            If TgtType(i) = CalType(j) Then
```

```
          calmatch = j
        End If
      Next j
      If calmatch > 0 Then
        calmatch = calmatch + TgtInclination(i) / 5
        For k = 1 To 7
'            prtstr1 = prtstr1 + Format(CalInPhase(calmatch, k), "####.###  ")
        Next k
        For k = 1 To 7
'            prtstr1 = prtstr1 + Format(CalQuadrature(calmatch, k), "####.###  ")
        Next k
'        Print #2, prtstr1

        For ii = ItemStart(i) To ItemEnd(i)
          iScalefactor = CalItotal(calmatch) / Itotal(ii)
          qScalefactor = CalQtotal(calmatch) / Qtotal(ii)
          idiff = 0#
          qdiff = 0#
          nfreq = 0
          For j = 1 To 7
            NormI(j) = InPhase(ii, j) * iScalefactor
            idiff = idiff + (NormI(j) - CalInPhase(calmatch, j)) ^ 2
            NormQ(j) = Quadrature(ii, j) * qScalefactor
            qdiff = qdiff + (NormQ(j) - CalQuadrature(calmatch, j)) ^ 2
          Next j
          ierror = Sqr(idiff / 7) / CalItotal(calmatch)
          qerror = Sqr(qdiff / 7) / CalQtotal(calmatch)
'          prtstr1 = Format(ii - ItemStart(i) + 1, "### ") + Format(Tdist(ii), "0.#### ")
'          prtstr1 = Format(ierror + qerror, "0.#### ") + Format(Tdist(ii), "0.#### ")
'          prtstr1 = prtstr1 + Format(Itotal(ii), "##### ") + Format(Qtotal(ii), "#####
")
'          prtstr1 = prtstr1 + Format(ierror + qerror, "0.#### ")
         prtstr1 = Format(Itotal(ii) + Qtotal(ii), "##### ")
          For k = 1 To 7
            prtstr1 = prtstr1 + Format(NormI(k) - CalInPhase(calmatch, k),
"####.###  ")
          Next k
          For k = 1 To 7
            prtstr1 = prtstr1 + Format(NormQ(k) - CalQuadrature(calmatch, k),
"####.###  ")
          Next k
          If (Itotal(ii) + Qtotal(ii) > 1000) Then Print #2, prtstr1
        Next ii
'        Print #2, prtstr1
'        Print #3, prtstr2
      End If
```

```
    Next i

    Close #2
'    Close #3

End Sub

Sub findmatches()

   UXO(1) = "20mm"
   UXO(2) = "57mm"
   UXO(3) = "60mm"
   UXO(4) = "2.75in"
   UXO(5) = "81mm"
   UXO(6) = "4.2in"
   UXO(7) = "152mm"
   UXO(8) = "155mm"
   UXO(9) = "76mm"
   UXO(10) = "105mm"
   UXO(11) = "5.0in"

'   ReadArea
   Open "allmatches.txt" For Output As #2

   For j = 1 To 11
      Score(j) = 0
   Next j
   For j = 1 To 11
      For k = 1 To 11
      Confusion(j, k) = 0
   Next k
   Next j

   For k = 1 To TgtNum
      If BestFit(k) > 0 Then
         i = BestFit(k)
         i = k
         FindQMatches (i)
         FindIMatches (i)
         FindCombinedMatches (i)
         Print #2, Format(TargetId(i), "@@@@@"), Format(Iz, "0.00  ")
         Print #2, "      InPhase Matches                         Quadrature Matches"
         For j = 1 To 8
            Print #2, ImatchUxo(j) & Space(25 - Len(ImatchUxo(j))) &
Format(ImatchError(j), "0.0000  "), _
                  QmatchUxo(j) & Space(25 - Len(QmatchUxo(j))) &
Format(QmatchError(j), "0.0000  "), _
                  CmatchUxo(j) & Space(25 - Len(CmatchUxo(j))) &
Format(CmatchError(j), "0.0000  ")
```

```
            If InStr(CmatchUxo(j), TgtType(k)) > 0 Then
               Score(j) = Score(j) + 1
            End If
         Next j
         For j = 1 To 11
            If TgtType(k) = UXO(j) Then Row = j
            If InStr(CmatchUxo(1), UXO(j)) > 0 Then col = j
         Next j
         Confusion(Row, col) = Confusion(Row, col) + 1

      Else
         Score(9) = Score(9) + 1
      End If
   Next k

   Print #2,
   For j = 1 To 8
      Print #2, Score(j), Format((Score(j) / (TgtNum - Score(9)) * 100), "##.#")
   Next j
   Print #2, "No matching cal data: ", Score(9)
   Print #2,
   Print #2, "UXO", UXO(1), UXO(2), UXO(3), UXO(4), UXO(5), UXO(6),
UXO(7), UXO(8)
   For j = 1 To 11
      Print #2, UXO(j), Confusion(j, 1), Confusion(j, 2), Confusion(j, 3), Confusion(j,
4), _
            Confusion(j, 5), Confusion(j, 6), Confusion(j, 7), Confusion(j, 8)
   Next j

   Close #2

End Sub



Private Sub Option1_Click(Index As Integer)

   NewArea (Index + 1)

End Sub

Private Sub Plot_Click()

   plotUXO.Show 1
   CurTarget = List3.ListIndex + 1

End Sub

Sub plotiq()
```

```
    j = NextPlot
    calmatch = 0
    For jj = 1 To NumCal
       If BestMatchUxo(j) = UxoType(jj) Then calmatch = jj
    Next jj

    MSChart1.RowCount = 7
    MSChart1.ColumnCount = 4
'    MSChart2.RowCount = 7
    MSChart1.Plot.SeriesCollection(1).SeriesMarker.Auto = False
    MSChart1.Plot.SeriesCollection(2).SeriesMarker.Auto = False
    MSChart1.Plot.SeriesCollection(3).SeriesMarker.Auto = False
    MSChart1.Plot.SeriesCollection(4).SeriesMarker.Auto = False
    MSChart1.Plot.SeriesCollection.Item(1).DataPoints(-1).Marker.Size = 100
    MSChart1.Plot.SeriesCollection.Item(1).DataPoints(-1).Marker.Style =
VtMarkerStyleFilledSquare
    MSChart1.Plot.SeriesCollection.Item(2).DataPoints(-1).Marker.Size = 100
    MSChart1.Plot.SeriesCollection.Item(2).DataPoints(-1).Marker.Style =
VtMarkerStyleFilledSquare
    MSChart1.Plot.SeriesCollection.Item(3).DataPoints(-1).Marker.Size = 100
    MSChart1.Plot.SeriesCollection.Item(3).DataPoints(-1).Marker.Style =
VtMarkerStylePlus
    MSChart1.Plot.SeriesCollection.Item(4).DataPoints(-1).Marker.Size = 100
    MSChart1.Plot.SeriesCollection.Item(4).DataPoints(-1).Marker.Style =
VtMarkerStylePlus

    If calmatch > 0 Then
       Scalefactorq = CalQtotal(calmatch) / Qtotal(j)
       Scalefactori = CalItotal(calmatch) / Itotal(j)
       With MSChart1
          For k = 1 To 7
             NormI = InPhase(j, k) * Scalefactori
             .Row = k
             .Column = 1
             .Data = CalInPhase(calmatch, k)
             .Column = 2
             .Data = NormI
'         Next k
'         .Title.Text = "Target " + TargetId(j) + " In Phase"
'      End With
'      With MSChart2
'         For k = 1 To 7
             NormQ = Quadrature(j, k) * Scalefactorq
             .Row = k
             .Column = 3
             .Data = CalQuadrature(calmatch, k)
             .Column = 4
             .Data = NormQ
```

```
            Next k
'           .Title.Text = "Target " + TargetId(j) + Chr(13) + Chr(10) + " Gem-3
Response"
        End With
    End If
End Sub

Sub plotloc()

With MSChart2
  .Plot.Axis(VtChAxisIdX).Intersection.Auto = False
  .Plot.Axis(VtChAxisIdX).Intersection.Point = -0.5
  .Plot.Axis(VtChAxisIdY).Intersection.Auto = False
  .Plot.Axis(VtChAxisIdY).Intersection.Point = -0.5
  k = NextItem
  j = List3.ListIndex + 1
  .RowCount = 1
  If j > 0 Then
    .ColumnCount = (ItemEnd(k) - ItemStart(k) + 2) * 2
    xcenter = TgtEasting(j)
    ycenter = TgtNorthing(j)
    .Row = .RowCount
    .Column = .ColumnCount - 1
    .Data = 0#
    .Column = .ColumnCount
    .Data = 0#
    .Plot.SeriesCollection.Item(.ColumnCount - 1).SeriesMarker.Auto = False
    .Plot.SeriesCollection.Item(.ColumnCount - 1).DataPoints(-1).Marker.Style =
VtMarkerStylePlus
    .Plot.SeriesCollection.Item(.ColumnCount - 1).DataPoints(-1).Marker.Visible =
True
    .Plot.SeriesCollection.Item(.ColumnCount - 1).DataPoints(-
1).Marker.Pen.VtColor.Red = 255
    .Plot.SeriesCollection.Item(.ColumnCount - 1).DataPoints(-
1).Marker.Pen.VtColor.Green = 0
    .Plot.SeriesCollection.Item(.ColumnCount - 1).DataPoints(-
1).Marker.Pen.VtColor.Blue = 0
  Else
    .ColumnCount = (ItemEnd(k) - ItemStart(k) + 1) * 2
    totalx = 0#
    totaly = 0#
    For i = ItemStart(k) To ItemEnd(k)
      totalx = totalx + Easting(i)
      totaly = totaly + Northing(i)
    Next i
    xcenter = totalx / (ItemEnd(k) - ItemStart(k) + 1)
    ycenter = totaly / (ItemEnd(k) - ItemStart(k) + 1)
  End If
```

```
  For i = ItemStart(k) To ItemEnd(k)
    .Plot.SeriesCollection.Item((i - ItemStart(k)) * 2 + 1).SeriesMarker.Auto = False
    .Plot.SeriesCollection.Item((i - ItemStart(k)) * 2 + 1).DataPoints(-
1).Marker.Style = VtMarkerStylePlus
    .Plot.SeriesCollection.Item((i - ItemStart(k)) * 2 + 1).DataPoints(-
1).Marker.Visible = True
    .Plot.SeriesCollection.Item((i - ItemStart(k)) * 2 + 1).DataPoints(-
1).Marker.Pen.VtColor.Red = 0
    .Plot.SeriesCollection.Item((i - ItemStart(k)) * 2 + 1).DataPoints(-
1).Marker.Pen.VtColor.Green = 0
    .Plot.SeriesCollection.Item((i - ItemStart(k)) * 2 + 1).DataPoints(-
1).Marker.Pen.VtColor.Blue = 0
    If BestMatchError(i) < Threshold Then
      .Plot.SeriesCollection.Item((i - ItemStart(k)) * 2 + 1).DataPoints(-
1).Marker.Pen.VtColor.Red = 0
'      .Plot.SeriesCollection.Item((i - ItemStart(k)) * 2 + 1).DataPoints(-
1).Marker.Pen.VtColor.Green = (Threshold - BestMatchError(i)) / Threshold * 255
      .Plot.SeriesCollection.Item((i - ItemStart(k)) * 2 + 1).DataPoints(-
1).Marker.Pen.VtColor.Green = 0
      .Plot.SeriesCollection.Item((i - ItemStart(k)) * 2 + 1).DataPoints(-
1).Marker.Pen.VtColor.Blue = 255
    End If
    If BestMatchError(i) < Threshold / 3 * 2 Then
      .Plot.SeriesCollection.Item((i - ItemStart(k)) * 2 + 1).DataPoints(-
1).Marker.Pen.VtColor.Red = 0
      .Plot.SeriesCollection.Item((i - ItemStart(k)) * 2 + 1).DataPoints(-
1).Marker.Pen.VtColor.Green = 255
      .Plot.SeriesCollection.Item((i - ItemStart(k)) * 2 + 1).DataPoints(-
1).Marker.Pen.VtColor.Blue = 255
    End If
    If BestMatchError(i) < Threshold / 3 Then
      .Plot.SeriesCollection.Item((i - ItemStart(k)) * 2 + 1).DataPoints(-
1).Marker.Pen.VtColor.Red = 255
      .Plot.SeriesCollection.Item((i - ItemStart(k)) * 2 + 1).DataPoints(-
1).Marker.Pen.VtColor.Green = 255
      .Plot.SeriesCollection.Item((i - ItemStart(k)) * 2 + 1).DataPoints(-
1).Marker.Pen.VtColor.Blue = 0
    End If
    If (i - ItemStart(k) = List2.ListIndex) Then
      .Plot.SeriesCollection.Item((i - ItemStart(k)) * 2 + 1).DataPoints(-
1).Marker.Style = VtMarkerStyleDiamond
'      .Plot.SeriesCollection.Item((i - ItemStart(k)) * 2 + 1).DataPoints(-
1).Marker.Pen.VtColor.Red = 255
'      .Plot.SeriesCollection.Item((i - ItemStart(k)) * 2 + 1).DataPoints(-
1).Marker.Pen.VtColor.Green = 255
'      .Plot.SeriesCollection.Item((i - ItemStart(k)) * 2 + 1).DataPoints(-
1).Marker.Pen.VtColor.Blue = 0
End If
```

```
        .Row = 1
        .Column = (i - ItemStart(k)) * 2 + 1
        .Data = Easting(i) - xcenter
        .Column = (i - ItemStart(k)) * 2 + 2
        .Data = Northing(i) - ycenter
    Next i
End With

End Sub

Private Sub Thresh_text_LostFocus()

    Threshold = Thresh_text.Text

End Sub
```

Io.bas

```
Public Sub ReadCal()

Open "c:\jpg\cal.txt" For Input As #1

i = 1
While Not EOF(1)
    For k = i To i + 36 Step 18
        Input #1, UxoType(k)
        CalType(k) = Mid(UxoType(k), 1, InStr(UxoType(k), ",") - 1)
        CalDepth(k) = Val(Mid(UxoType(k), InStr(UxoType(k), ",") + 1))
        CalInclination(k) = Val(Mid(UxoType(k), InStr(UxoType(k), "cm,") + 3))
        For j = 1 To 7
            Input #1, CalInPhase(k, j)
        Next j
        Input #1, UxoType(k)
        For j = 1 To 7
            Input #1, CalQuadrature(k, j)
        Next j
    Next k
    ichar = InStr(UxoType(i), "90")
    For k = i + 1 To i + 17
        UxoType(k) = UxoType(i)
        CalType(k) = CalType(i)
        CalDepth(k) = CalDepth(i)
        CalInclination(k) = 90 - (k - i) * 5
        Mid(UxoType(k), ichar, 2) = Format(90 - (k - i) * 5, "@@")
        For j = 1 To 7
            CalInPhase(k, j) = CalInPhase(i, j) + (k - i) / 18# * (CalInPhase(i + 18, j) -
CalInPhase(i, j))
```

```
            CalQuadrature(k, j) = CalQuadrature(i, j) + (k - i) / 18# * (CalQuadrature(i +
18, j) - CalQuadrature(i, j))
        Next j
    Next k
    For k = i + 19 To i + 35
        UxoType(k) = UxoType(i + 36)
        CalType(k) = CalType(i)
        CalDepth(k) = CalDepth(i)
        CalInclination(k) = 0 - (k - i - 18) * 5
        Mid(UxoType(k), ichar, 3) = Format(0 - (k - i - 18) * 5, "@@@")
        For j = 1 To 7
            CalInPhase(k, j) = CalInPhase(i + 18, j) + (k - i - 18) / 18# * (CalInPhase(i +
36, j) - CalInPhase(i + 18, j))
            CalQuadrature(k, j) = CalQuadrature(i + 18, j) + (k - i - 18) / 18# *
(CalQuadrature(i + 36, j) - CalQuadrature(i + 18, j))
        Next j
    Next k

    i = i + 37
Wend
NumCal = i - 1
Close #1

End Sub

Public Sub ReadArea(area As Integer)

If area = 1 Then
    Open "c:\jpg\Tarea1_bckc.txt" For Input As #1
ElseIf area = 2 Then
    Open "c:\jpg\Tarea2_bckc.txt" For Input As #1
Else
    Open "c:\jpg\Tarea3_bckc.txt" For Input As #1
End If

i = 1
ii = 0
While Not EOF(1)

    ' Read a point
    For j = 1 To 7
        Input #1, Quadrature(i, j)
    Next j
    For j = 1 To 7
        Input #1, InPhase(i, j)
    Next j
    Input #1, Northing(i)
    Input #1, Easting(i)
    Input #1, TargetId(i)
```

```
    'Decode target id
'   If area > 1 Then
'      tempstr = Left(TargetId(i), 1) + Mid(TargetId(i), 4)
'      TargetId(i) = tempstr
'   End If
    cpos = InStr(TargetId(i), "-")
    If Mid(TargetId(i), cpos, 2) = "-0" Then
       tempstr = Mid(TargetId(i), 1, cpos - 1)
    Else
       tempstr = Str(area) + Mid(TargetId(i), cpos)
    End If
    TargetId(i) = Trim(tempstr)

    'Calculate sum of all frequencies
    totali = 0
    totalq = 0
    For j = 1 To 7
       totali = totali + Abs(InPhase(i, j))
       totalq = totalq + Abs(Quadrature(i, j))
    Next j
    Itotal(i) = totali
    Qtotal(i) = totalq

    'Calculate distance to actual target
    Tdist(i) = -1
    For j = 1 To TgtNum
       If TargetId(i) = TgtId(j) Then
          dx = TgtEasting(j) - Easting(i)
          dy = TgtNorthing(j) - Northing(i)
          Tdist(i) = Sqr((TgtNorthing(j) - Northing(i)) ^ 2 + (TgtEasting(j) - Easting(i))
^ 2)
          Exit For
       End If
    Next j

    'Keep track of each separate item
    If (ii > 0) Then
       If TargetId(i) <> ItemId(ii) Then
          ii = ii + 1
          ItemEnd(ii - 1) = i - 1
          ItemStart(ii) = i
          ItemId(ii) = TargetId(i)
       End If
    Else
       ii = 1
       ItemId(ii) = TargetId(i)
       ItemStart(ii) = i
    End If
```

```
  i = i + 1
Wend

NumPoints = i - 1
NumItems = ii
ItemEnd(ii) = i - 1

Close #1

End Sub


Public Sub ReadTargets(area As Integer)

  If area = 1 Then
    Open "c:\jpg\area1atargets.txt" For Input As #1
  ElseIf area = 2 Then
    Open "c:\jpg\area2atargets.txt" For Input As #1
  Else
    Open "c:\jpg\area3atargets.txt" For Input As #1
  End If

  i = 1
  While Not EOF(1)
    Input #1, TgtId(i), TgtNorthing(i), TgtEasting(i), Depth, TgtAzimuth(i),
TgtInclination(i), TgtType(i)
    TgtDepth(i) = Depth * 100
    i = i + 1
  Wend
  Close #1

  TgtNum = i - 1
  Close #1

End Sub

Public Sub ReadClutter()

  Open "c:\jpg\area123Clutter.txt" For Input As #1
  i = 1
  While Not EOF(1)
    Input #1, TgtNorthing(i), TgtEasting(i), TgtId(i)
    i = i + 1
  Wend
  TgtNum = i - 1
  Close #1

End Sub
```

Globals.bas

```
Global UxoType(1 To 10000) As String
Global CalInPhase(1 To 10000, 1 To 7) As Double
Global CalQuadrature(1 To 10000, 1 To 7) As Double
Global CalType(1 To 10000) As String
Global CalDepth(1 To 10000) As Integer
Global CalInclination(1 To 10000) As Integer
Global CalQtotal(1 To 10000) As Double
Global CalItotal(1 To 10000) As Double
Global NumCal As Integer
Global InPhase(1 To 10000, 1 To 7) As Double
Global Quadrature(1 To 10000, 1 To 7) As Double
Global Northing(1 To 10000) As Double
Global Easting(1 To 10000) As Double
Global TargetId(1 To 10000) As String
Global Qtotal(1 To 10000) As Double
Global Itotal(1 To 10000) As Double
Global Tdist(1 To 10000) As Double
Global NumPoints As Integer
Global IZero(1 To 10000) As Double
Global CmatchUxo(1 To 10) As String
Global BestMatchUxo(1 To 10000) As String
Global CmatchError(1 To 10) As Double
Global BestMatchError(1 To 10000) As Double
Global Iz As Double
Global TgtId(1 To 500) As String
Global TgtEasting(1 To 500) As Double
Global TgtNorthing(1 To 500) As Double
Global TgtDepth(1 To 500) As Integer
Global TgtAzimuth(1 To 500) As Integer
Global TgtInclination(1 To 500) As Integer
Global TgtType(1 To 500) As String
Global TgtNum As Integer
Global ItemId(1 To 10000) As String
Global ItemStart(1 To 10000) As Integer
Global ItemEnd(1 To 10000) As Integer
Global ItemMinDist(1 To 10000) As Double
Global NumItems As Integer


Global NextPlot As Integer
Global NextItem As Integer
Global BestFit(1 To 10000) As Integer
Global BestCal(1 To 10000) As Integer
Global Score(1 To 11) As Integer
Global Confusion(1 To 12, 1 To 12) As Integer
Global UXO(1 To 12) As String
```

```
Global SelFreq(1 To 7) As Boolean
Global Threshold As Double
Global ShowBest As Boolean
Global CurTarget As Integer
```

PlotUXO.frm

```
Private Sub Cancel_Click()

  NextPlot = NextPlot + 1
  Unload Me
  plotUXO.Show

End Sub

Private Sub Form_Load()

    j = NextPlot
    calmatch = 0
    For jj = 1 To NumCal
      If BestMatchUxo(j) = UxoType(jj) Then calmatch = jj
    Next jj

    MSChart1.RowCount = 7
    MSChart2.RowCount = 7
    MSChart1.Plot.SeriesCollection(1).SeriesMarker.Auto = False
    MSChart1.Plot.SeriesCollection(2).SeriesMarker.Auto = False
    MSChart2.Plot.SeriesCollection(1).SeriesMarker.Auto = False
    MSChart2.Plot.SeriesCollection(2).SeriesMarker.Auto = False
    MSChart1.Plot.SeriesCollection.Item(1).DataPoints(-1).Marker.Size = 100
    MSChart1.Plot.SeriesCollection.Item(2).DataPoints(-1).Marker.Size = 100
    MSChart2.Plot.SeriesCollection.Item(1).DataPoints(-1).Marker.Size = 100
    MSChart2.Plot.SeriesCollection.Item(2).DataPoints(-1).Marker.Size = 100

    If calmatch > 0 Then
      Scalefactorq = CalQtotal(calmatch) / Qtotal(j)
      Scalefactori = CalItotal(calmatch) / Itotal(j)
      With MSChart1
        For k = 1 To 7
          NormI = InPhase(j, k) * Scalefactori
          .Row = k
          .Column = 1
          .Data = CalInPhase(calmatch, k)
          .ColumnLabel = UxoType(calmatch)
          .Column = 2
          .Data = NormI
          .ColumnLabel = TargetId(j)
```

```
            Next k
            .Title.Text = "Target " + TargetId(j) + " In Phase"
        End With
        With MSChart2
            For k = 1 To 7
                NormQ = Quadrature(j, k) * Scalefactorq
                .Row = k
                .Column = 1
                .Data = CalQuadrature(calmatch, k)
                .ColumnLabel = UxoType(calmatch)
                .Column = 2
                .Data = NormQ
                .ColumnLabel = TargetId(j)
            Next k
            .Title.Text = "Target " + TargetId(j) + " Quadrature"
        End With
    End If

  PrintForm

End Sub
```

GridScan Program

```
Sub dpos_maxima()
Rem this subprogram locates the maxima in the dpos box and outputs them
Rem it also writes out the data as inphase for the area and quad for the area
Rem the case of Tag_this true is the global histogram of the entire data set
Rem false is the local target case
Open wheredata$ For Input As #1
Open dposq$ For Output As #2
Open dposi$ For Output As #3
Do While EOF(1) = False
    icount = icount + 1
    Rem read in the data for the selected data segment( global and partial)
    For j = 1 To 14
      Input #1, Rawdata(0, j, icount), Rawdata(1, j, icount)
    Next j
    Input #1, posdata(0, icount), posdata(1, icount)
    Input #1, dummy$
    For j = 8 To 14
      Print #2, Rawdata(0, j, icount); " , ";
      Print #3, Rawdata(1, j, icount); " , ";
    Next j
    Print #2, posdata(0, icount); " , "; posdata(1, icount); " , "; dummy$
    Print #3, posdata(0, icount); " , "; posdata(1, icount); " , "; dummy$
Loop
Close #1
Close #2
Close #3




End Sub
Sub lochist_this()
Rem the case of Tag_this true is the global histogram of the entire data set
Rem false is the local target case

Floop = n
For m = 1 To Floop
  Rem inserting code for  Call initalizelocal and get
  Rem ******************** ******************** ********************
  Rem ******************** ******************** ********************
  Rem this file does not contain the targets
  Rem if you try to locate target maxima from here you get junk
  fl = "C:\WINDOWS\Desktop\Hist_temp\" + TVal + "hist_where_" + id$(m) +
".txt"
  Rem initalize the position extrema
```

```
    pos0max = 0
    pos0min = 0
    pos1max = 0
    pos1min = 0
    bb = 0
    Rem initalize the signal extrema
    For k = 1 To 8
        quadmin(k) = 0
        quadmax(k) = 0
        inmin(k) = 0
        inmax(k) = 0
    Next k
    For i = 0 To 1
        For j = 0 To 16
            For k = 0 To 15
                Maxdata(i, j, k) = 0
            Next k
        Next j
    Next i
    Open fl For Input As #1
        'MsgBox ("initalizelocal Finished")
    Rem ******************** ******************** ********************
    Rem ******************** ******************** ********************
    icount = 0
    Rem find the extrema
    Rem INSERING CODE FROM Call locateextrema and getting rid of global stuff
    Rem ******************** ******************** ********************
    Rem ******************** ******************** ********************
    Do While EOF(1) = False
        icount = icount + 1
        Rem read in the data for the selected data segment( global and partial)
        For j = 1 To 14
                Input #1, Rawdata(0, j, icount), Rawdata(1, j, icount)
                Maxdata(0, j, 1) = Rawdata(0, j, icount)
                Maxdata(1, j, 1) = Rawdata(1, j, icount)
        Next j
            Input #1, posdata(0, icount), posdata(1, icount)
            Rem locate position extrema
            Maxdata(0, 0, 3) = posdata(0, icount)
            Maxdata(1, 0, 3) = posdata(1, icount)
            Input #1, Rawdata(0, 15, incount)
            Maxdata(0, 15, 1) = Rawdata(0, 15, icount)
          For j = 8 To 14
            If Rawdata(0, j, icount) > 8000 Then Rawdata(0, j, icount) = 0
            If Rawdata(1, j, icount) > 8000 Then Rawdata(1, j, icount) = 0
            If Rawdata(0, j, icount) < quadmin(j - 7) Then quadmin(j - 7) =
Rawdata(0, j, icount)
            If Rawdata(0, j, icount) > quadmax(j - 7) Then quadmax(j - 7) =
Rawdata(0, j, icount)
```

```
            If Rawdata(1, j, icount) < inmin(j - 7) Then inmin(j - 7) = Rawdata(1, j,
icount)
            If Rawdata(1, j, icount) > inmax(j - 7) Then inmax(j - 7) = Rawdata(1, j,
icount)
            If bb = 0 Then
               pos0max = posdata(0, icount)
               pos0min = posdata(0, icount)
               pos1max = posdata(1, icount)
               pos1min = posdata(1, icount)
               bb = 1
            End If
            If pos0max < posdata(0, icount) Then
               pos0max = posdata(0, icount)
               Label9.Caption = Str(pos0max) + "  " + Str(pos1max)
            End If
            If pos0min > posdata(0, icount) Then
               pos0min = posdata(0, icount)
               Label10.Caption = Str(pos0min) + "  " + Str(pos1min)
            End If
            If pos1max < posdata(1, icount) Then
               pos1max = posdata(1, icount)
               Label9.Caption = Str(pos0max) + "  " + Str(pos1max)
            End If
            If pos1min < posdata(1, icount) Then
               pos1min = posdata(1, icount)
               Label9.Caption = Str(pos0min) + "  " + Str(pos1min)
            End If
      Rem If icount / 25000 = Int(icount / 25000) Then MsgBox (Str(posdata(0,
icount)) + "  " + Str(posdata(1, icount)))
      Next j

      Maxdata(0, 16, 1) = 0
      Maxdata(1, 16, 1) = 0
      For i = 8 To 14
         Maxdata(0, 16, 1) = Maxdata(0, 16, 1) + Abs(Maxdata(0, i, 1)) +
Abs(Maxdata(1, i, 1))
      Next i
      If Maxdata(0, 16, 1) >= Maxdata(0, 16, 2) Then
         Maxdata(0, 16, 2) = Maxdata(0, 16, 1)
         For i = 1 To 16
            Maxdata(0, i, 2) = Maxdata(0, i, 1)
            Maxdata(1, i, 2) = Maxdata(1, i, 1)
         Next i
         MaxPos(0) = Maxdata(0, 0, 3)
         MaxPos(1) = Maxdata(1, 0, 3)
      End If

   Loop
   Rem find the minimum values for all seven frequency both signals
```

```
   gquadmin = quadmin(1)
   ginmin = inmin(1)
   For i = 2 To 7
    If gquadmin > quadmin(i) Then gquadmin = quadmin(i)
    If ginmin > inmin(i) Then ginmin = inmin(i)
   Next i
   'MsgBox ("localextrema Finished")
   Rem ******************** ******************** ********************
   Rem ******************** ******************** ********************
   Rem output maxima data for the local case
   Rem this is where the problem was
   Rem localout is putting out the maxima in the dbk - dpos box
   Rem not the dpos box
   Rem I have gotten rid of Call localout
   jcount = icount
   Close #1
   Rem histogram in amplitude for each frequnecy and phase
   Call dohist
   Rem ********************
   Rem put out histogram for each
   Rem filenames are quadf1, inf1, ...
   Rem get these names
   Rem for the global file
   Call localhistout
Next m
End Sub
Sub new_hist_this()
Rem note that tag_this hasbeen removed and this code will only deal wiht the
Rem global data set
Rem this subprogram gets the data read in and generates a histogram for the
Rem entire area under investigation as found in f1
   Open rawdataa$ For Input As #1
   For i = 1 To 30
      Input #1, head$(i)
   Next i
   icount = 0
   Rem find the extrema
   Rem insering instead of calling Call locateextrema
   Rem ******************** ******************** ********************
   Rem ******************** ******************** ********************
   Do While EOF(1) = False
      icount = icount + 1
      Rem read in the data for the selected data segment(global and partial)
      For j = 1 To 14
            Input #1, Rawdata(0, j, icount), Rawdata(1, j, icount)

      Next j
      Input #1, posdata(0, icount), posdata(1, icount)
      For j = 8 To 14
```

```
        If Rawdata(0, j, icount) > 8000 Then Rawdata(0, j, icount) = 0
        If Rawdata(1, j, icount) > 8000 Then Rawdata(1, j, icount) = 0
        If Rawdata(0, j, icount) < quadmin(j - 7) Then quadmin(j - 7) = Rawdata(0,
j, icount)
        If Rawdata(0, j, icount) > quadmax(j - 7) Then quadmax(j - 7) = Rawdata(0,
j, icount)
        If Rawdata(1, j, icount) < inmin(j - 7) Then inmin(j - 7) = Rawdata(1, j,
icount)
        If Rawdata(1, j, icount) > inmax(j - 7) Then inmax(j - 7) = Rawdata(1, j,
icount)
        If bb = 0 Then
          pos0max = posdata(0, icount)
          pos0min = posdata(0, icount)
          pos1max = posdata(1, icount)
          pos1min = posdata(1, icount)
          bb = 1
        End If
        If pos0max < posdata(0, icount) Then
          pos0max = posdata(0, icount)
          Label9.Caption = Str(pos0max) + "  " + Str(pos1max)
        End If
        If pos0min > posdata(0, icount) Then
          pos0min = posdata(0, icount)
          Label10.Caption = Str(pos0min) + "  " + Str(pos1min)
        End If
        If pos1max < posdata(1, icount) Then
          pos1max = posdata(1, icount)
          Label9.Caption = Str(pos0max) + "  " + Str(pos1max)
        End If
        If pos1min < posdata(1, icount) Then
          pos1min = posdata(1, icount)
          Label9.Caption = Str(pos0min) + "  " + Str(pos1min)
        End If
      Next j
    Loop
    Rem find the minimum values for all seven frequency both signals
    gquadmin = quadmin(1)
    ginmin = inmin(1)
    For i = 2 To 7
      If gquadmin > quadmin(i) Then gquadmin = quadmin(i)
      If ginmin > inmin(i) Then ginmin = inmin(i)
    Next i
    'MsgBox ("localextrema Finished")
    Rem ******************** ******************** ********************
    Rem ******************** ******************** ********************
    numtosearch = icount
    Rem I cahanged the variable name to numtosearch in here
    Rem I left the one below because I am not sure where it is used again
    jcount = icount
```

```
Close #1
   Rem histogram in amplitude for each frequnecy and phase
   Rem ******************** ******************** ********************
   Rem ******************** ******************** ********************
   Rem replacing Call dohist wiht code found there
   Rem init array space
   For j = 1 To 8000
      For i = 1 To 7
         histo(0, i, j) = 0
         histo(1, i, j) = 0
      Next i
   Next j

   n = 1
   Rem calculates histgrams for all cases
   For icount = 1 To numtosearch
      For k = 8 To 14
         j = k - 7
         histo0index = Int(Rawdata(0, k, icount) - gquadmin)
         histo1index = Int(Rawdata(1, k, icount) - ginmin)
         histo(0, j, histo0index) = histo(0, j, histo0index) + 1
         histo(1, j, histo1index) = histo(1, j, histo1index) + 1
      Next k
   Next icount
   Rem find the mean value for the histogram
   Rem put it at the end of the histogram
   Rem sum up the number of items at each location
   For i = 1 To 7
      histsum(0, i) = 0
      histsum(1, i) = 0
   Next i
   For i = 1 To 7
      num0 = 0
      num1 = 0
      For j = 1 To 8000
         num0 = num0 + Abs(histo(0, i, j))
         num1 = num1 + Abs(histo(1, i, j))
         histsum(0, i) = histsum(0, i) + j * Abs(histo(0, i, j))
         histsum(1, i) = histsum(1, i) + j * Abs(histo(1, i, j))
      Next j
      histmean(0, i) = histsum(0, i) / num0
      histmean(1, i) = histsum(1, i) / num1
   Next i
   Rem ********************************************
   'MsgBox ("Dohist Finished")

   Rem ******************** ******************** ********************
   Rem ******************** ******************** ********************
```

```
Rem *********************
   Rem put out histogram for each
   Rem filenames are quadfl, infl, ...
   Rem get these names
   Rem for the global file

   Rem ******************** ******************** ********************
   Rem ******************** ******************** ********************
   Rem i am replacing Call globalhistout wiht the code
   Rem this produces a the files found in f2
   Rem I dont know why we still need them
   Rem I think this should all be one file
   Open histonames$ For Input As #1
      For i = 1 To 7
         Input #1, histoname(0, i)
         Input #1, histoname(1, i)
         'Msgbox (histoname(0, i) + "  " + histoname(1, i))
      Next i
   Close #1
   For i = 1 To 7
      Open histoname(0, i) For Output As #2
      Open histoname(1, i) For Output As #3
      Print #2, 8000; " qmin, "; quadmin(i); ", qmax "; quadmax(i)
      Print #3, 8000; " imin, "; inmin(i); ", imax "; inmax(i)
      For j = 1 To 8000
            Print #2, histo(0, i, j)
            Print #3, histo(1, i, j)
         Next j
      Close #2
      Close #3
   Next i
   'MsgBox ("globalhistout Finished")
End Sub
Sub dohist()
Rem init array
   For j = 1 To 8000
      For i = 1 To 7
         histo(0, i, j) = 0
         histo(1, i, j) = 0
      Next i
   Next j
   n = 1
   Rem calculates histgrams for all cases
   For icount = 1 To jcount
      For k = 8 To 14
         j = k - 7
         histo0index = Int(Rawdata(0, k, icount) - gquadmin)
         histo1index = Int(Rawdata(1, k, icount) - ginmin)
         histo(0, j, histo0index) = histo(0, j, histo0index) + 1
```

```
        histo(1, j, histo1index) = histo(1, j, histo1index) + 1
      Next k
   Next icount
   Rem find the mean value for the histogram
   Rem put it at the end of the histogram
   Rem sum up the number of items at each location
   For i = 1 To 7
      histsum(0, i) = 0
      histsum(1, i) = 0
   Next i
   For i = 1 To 7
   'MsgBox ("start")
      num0 = 0
      num1 = 0
      For j = 1 To 8000
         num0 = num0 + Abs(histo(0, i, j))
         num1 = num1 + Abs(histo(1, i, j))
         histsum(0, i) = histsum(0, i) + j * Abs(histo(0, i, j))
         histsum(1, i) = histsum(1, i) + j * Abs(histo(1, i, j))
      Next j
      histmean(0, i) = histsum(0, i) / num0
      histmean(1, i) = histsum(1, i) / num1
   Next i
   Rem ******************************************
   'MsgBox ("Dohist Finished")
End Sub
Sub globalhistout()
 Open histonames$ For Input As #1
         For i = 1 To 7
            Input #1, histoname(0, i)
            Input #1, histoname(1, i)
            'Msgbox (histoname(0, i) + "  " + histoname(1, i))
         Next i
      Close #1
      For i = 1 To 7
         Open histoname(0, i) For Output As #2
         Open histoname(1, i) For Output As #3
         Print #2, 8000; " qmin, "; quadmin(i); ", qmax "; quadmax(i); ", pos0min ";
Str$(pos0min); ", pos0max "; Str$(pos0max); ", pos1min "; Str$(pos1min); ", pos1max ";
Str$(pos1max)
         Print #3, 8000; " imin, "; inmin(i); ", imax "; inmax(i); ", pos0min ";
Str$(pos0min); ", pos0max "; Str$(pos0max); ", pos1min "; Str$(pos1min); ", pos1max ";
Str$(pos1max)
            For j = 1 To 8000
               Print #2, histo(0, i, j)
               Print #3, histo(1, i, j)
            Next j
         Close #2
         Close #3
```

```
      Next i
    'MsgBox ("globalhistout Finished")
End Sub
Sub localhistout()
      f2 = "C:\WINDOWS\Desktop\Hist_temp\" + TVal + "hist_where_" + id$(m) +
"_Q_" + ".txt"
      f3 = "C:\WINDOWS\Desktop\Hist_temp\" + TVal + "hist_where_" + id$(m) +
"_I_" + ".txt"
      f6 = "C:\WINDOWS\Desktop\Hist_temp\" + TVal + "hist_mean_" + AreaNum +
"_Q.txt"
      f7 = "C:\WINDOWS\Desktop\Hist_temp\" + TVal + "hist_mean_" + AreaNum +
"_I.txt"
      Open f2 For Output As #2
      Open f3 For Output As #3
      Open f6 For Append As #6
      Open f7 For Append As #7
      Print #2, 8000; " , "
      gquadmin = quadmin(1)
      gquadmax = quadmax(1)
      ginmin = inmin(1)
      ginmax = inmax(1)
      For i = 1 To 7
        Print #2, quadmin(i); " , "; quadmax(i); " , ";
        Print #3, inmin(i); ", "; inmax(i); " ,  ";
      Next i
      Rem output section for target specific file
      Print #2, gquadmin; ", pos0min, "; Str$(pos0min);
      Print #3, ginmin; ", pos0min, "; Str$(pos0min);
      For j = 1 To 8000
        Hgrp0 = ""
        Hgrp1 = ""
        For i = 1 To 7
          Hgrp0 = Hgrp0 + Str$(histo(0, i, j)) + ", "
          Hgrp1 = Hgrp1 + Str$(histo(1, i, j)) + ", "
        Next i
        Print #2, Hgrp0
        Print #3, Hgrp1
      Next j
      Rem print a blank line and then the histogram offset and mean
      Print #2, ""
      Print #3, ""
      Print #2, "mean values"
      Print #3, "mean values"
      Print #6, gquadmin; " , ";
      Print #7, ginmin; " , ";
      For i = 1 To 7
        Print #2, histmean(0, i); " , ";
        Print #3, histmean(1, i); " , ";
        Print #6, histmean(0, i); " , ";
```

```
          Print #7, histmean(1, i); " , ";
        Next i
        Print #2, ""
        Print #3, ""
        Print #6, id$(m); ""
        Print #7, id$(m); ""
        Close #2
        Close #3
        Close #6
        Close #7
   'MsgBox ("localhistout Finished")
End Sub
Sub localout()
   Rem this should be inside the dpos box without the dbk box
   Rem it is currenlty the dbk box wihtout the dpos box
   f4 = "C:\WINDOWS\Desktop\Hist_temp\" + TVal + "Max_where_" + AreaNum +
"_Q.txt"
   f5 = "C:\WINDOWS\Desktop\Hist_temp\" + TVal + "Max_where_" + AreaNum +
"_I.txt"
   Open f4 For Append As #4
   Open f5 For Append As #5
   For j = 8 To 14
      Print #4, Maxdata(0, j, 2); ",  ";
      Print #5, Maxdata(1, j, 2); ",  ";
   Next j
   Print #4, MaxPos(0); ",  "; MaxPos(1); ", "; id$(m)
   Print #5, MaxPos(0); ",  "; MaxPos(1); ", "; id$(m)
   Close #4
   Close #5
   Maxdata(0, 16, 2) = 0
   'MsgBox ("localout Finished")
End Sub

Sub locateextrema()
Do While EOF(1) = False
     icount = icount + 1
     Rem read in the data for the selected data segment( global and partial)
     For j = 1 To 14
            Input #1, Rawdata(0, j, icount), Rawdata(1, j, icount)
            Maxdata(0, j, 1) = Rawdata(0, j, icount)
            Maxdata(1, j, 1) = Rawdata(1, j, icount)
     Next j

          Input #1, posdata(0, icount), posdata(1, icount)
          Rem locate position extrema
          Maxdata(0, 0, 3) = posdata(0, icount)
          Maxdata(1, 0, 3) = posdata(1, icount)
```

```
        If Tag_This = False Then
          Input #1, Rawdata(0, 15, incount)
          Maxdata(0, 15, 1) = Rawdata(0, 15, icount)
        End If

      For j = 8 To 14
        If Rawdata(0, j, icount) > 8000 Then Rawdata(0, j, icount) = 0
        If Rawdata(1, j, icount) > 8000 Then Rawdata(1, j, icount) = 0
        If Rawdata(0, j, icount) < quadmin(j - 7) Then quadmin(j - 7) = Rawdata(0, j,
icount)
        If Rawdata(0, j, icount) > quadmax(j - 7) Then quadmax(j - 7) = Rawdata(0, j,
icount)
        If Rawdata(1, j, icount) < inmin(j - 7) Then inmin(j - 7) = Rawdata(1, j, icount)
        If Rawdata(1, j, icount) > inmax(j - 7) Then inmax(j - 7) = Rawdata(1, j,
icount)

        If bb = 0 Then
          pos0max = posdata(0, icount)
          pos0min = posdata(0, icount)
          pos1max = posdata(1, icount)
          pos1min = posdata(1, icount)
          bb = 1
        End If
        If pos0max < posdata(0, icount) Then
          pos0max = posdata(0, icount)
          Label9.Caption = Str(pos0max) + "  " + Str(pos1max)
        End If
        If pos0min > posdata(0, icount) Then
          pos0min = posdata(0, icount)
          Label10.Caption = Str(pos0min) + "  " + Str(pos1min)
        End If
        If pos1max < posdata(1, icount) Then
          pos1max = posdata(1, icount)
          Label9.Caption = Str(pos0max) + "  " + Str(pos1max)
        End If
        If pos1min < posdata(1, icount) Then
          pos1min = posdata(1, icount)
          Label9.Caption = Str(pos0min) + "  " + Str(pos1min)
        End If
    Rem If icount / 25000 = Int(icount / 25000) Then MsgBox (Str(posdata(0, icount)) +
"  " + Str(posdata(1, icount)))
    Next j

    Maxdata(0, 16, 1) = 0
    Maxdata(1, 16, 1) = 0
    For i = 8 To 14
      Maxdata(0, 16, 1) = Maxdata(0, 16, 1) + Abs(Maxdata(0, i, 1)) +
Abs(Maxdata(1, i, 1))
```

```
        Next i
        If Maxdata(0, 16, 1) >= Maxdata(0, 16, 2) Then
           Maxdata(0, 16, 2) = Maxdata(0, 16, 1)
           For i = 1 To 16
              Maxdata(0, i, 2) = Maxdata(0, i, 1)
              Maxdata(1, i, 2) = Maxdata(1, i, 1)
           Next i
           MaxPos(0) = Maxdata(0, 0, 3)
           MaxPos(1) = Maxdata(1, 0, 3)
        End If

     Loop
     Rem find the minimum values for all seven frequency both signals
     gquadmin = quadmin(1)
     ginmin = inmin(1)
     For i = 2 To 7
      If gquadmin > quadmin(i) Then gquadmin = quadmin(i)
      If ginmin > inmin(i) Then ginmin = inmin(i)
     Next i
     'MsgBox ("localextrema Finished")
  End Sub
  Sub initalizelocal()
  fl = "C:\WINDOWS\Desktop\Hist_temp\" + TVal + "hist_where_" + id$(m) + ".txt"
  If Dir(fl) = "" Then
     Open fl For Output As #9
        Print #9, "1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,
  " + id$(m)
     Close #9
  End If
        Rem initalize the position extrema
        pos0max = 0
        pos0min = 0
        pos1max = 0
        pos1min = 0
        bb = 0
        Rem initalize the signal extrema
        For k = 1 To 8
           quadmin(k) = 0
           quadmax(k) = 0
           inmin(k) = 0
           inmax(k) = 0
        Next k
        For i = 0 To 1
           For j = 0 To 16
              For k = 0 To 15
                 Maxdata(i, j, k) = 0
              Next k
           Next j
```

```
        Next i
        Open f1 For Input As #1
        'MsgBox ("initalizelocal Finished")
    End Sub




    Private Sub AllIt_Click()

    If AllIt.Checked = False Then
       TarIt.Checked = False
       FragIt.Checked = False
       AllIt.Checked = True
       GphxIt.Checked = False
    End If

    End Sub

    Private Sub AOneIt_Click()

    If AOneIt.Checked = False Then
       AOneIt.Checked = True
       ATwoIt.Checked = False
       AThreeIt.Checked = False
    End If

    End Sub

    Private Sub AThreeIt_Click()

    If AThreeIt.Checked = False Then
       AOneIt.Checked = False
       ATwoIt.Checked = False
       AThreeIt.Checked = True
    End If

    End Sub

    Private Sub ATwoIt_Click()

    If ATwoIt.Checked = False Then
       AOneIt.Checked = False
       ATwoIt.Checked = True
       AThreeIt.Checked = False
    End If

    End Sub
```

```
Private Sub Command2_Click()
Rem determine which area to get data from
If AOneIt.Checked = True Then
   AreaNum = "1"
End If
If ATwoIt.Checked = True Then
   AreaNum = "2"
End If
If AThreeIt.Checked = True Then
   AreaNum = "3"
End If
If TarIt.Checked = 1 Then
   TVal = "T"
End If
If FragIt.Checked = 1 Then
   TVal = "F"
End If
If AllIt.Checked = 1 Then
   TVal = "A"
End If
If GphxIt.Checked = 1 Then
   TVal = "GT"
End If


Form1.MousePointer = vbHourglass
'f1 = wheredata$

f1 = "C:\WINDOWS\Desktop\" + TVal + "where_" + AreaNum + "a_data.txt"
f2 = "C:\WINDOWS\Desktop\Hist_temp\" + TVal + "hist_mean_" + AreaNum +
"_Q.txt"
f3 = "C:\WINDOWS\Desktop\Hist_temp\" + TVal + "hist_mean_" + AreaNum + "_I.txt"
f4$ = "c:\windows\desktop\Hist_temp\" + TVal + "Area" + AreaNum + "a_data_q.txt"
f5$ = "c:\windows\desktop\Hist_temp\" + TVal + "Area" + AreaNum + "a_data_i.txt"
f6$ = "c:\windows\desktop\Hist_temp\" + TVal + "Area" + AreaNum +
"a_data_q_bckc.txt"
f7$ = "c:\windows\desktop\Hist_temp\" + TVal + "Area" + AreaNum +
"a_data_i_bckc.txt"
Open f1 For Input As #1
Open f2 For Input As #2
Open f3 For Input As #3

icount = 0
Do While EOF(1) = False
     icount = icount + 1
     Rem read in the data for the selected data segment( global and partial)
```

```
        For i = 1 To 7
            Input #1, dum1, dum2
        Next i
        For j = 1 To 7
                Input #1, Rawdata(0, j, icount), Rawdata(1, j, icount)
        Next j
        Input #1, posdata(0, icount), posdata(1, icount), RawId$(icount)
        'MsgBox (RawId$(icount))
Loop
Close #1
NumSigs = icount
icount = 0
Do While EOF(2) = False
    icount = icount + 1
    For i = 0 To 7
        Input #2, QBak(i, icount)
    Next i
    Input #2, BakId$(icount)
    'MsgBox (BakId$(icount))

Loop
NumIds = icount
Close #2
icount = 0
Do While EOF(3) = False
    icount = icount + 1
    For i = 0 To 7
        Input #3, IBak(i, icount)
    Next i
    Input #3, dummy$
    'MsgBox (dummy$)
Loop
Close #3
If icount <> NumIds Then MsgBox ("soemthing's wrong")
Rem this takes care of writing out all that was in the box dpos
Open f4$ For Output As #4
Open f5$ For Output As #5
For i = 1 To NumSigs
    For j = 1 To 7
        Print #4, Rawdata(0, j, i); " , ";
        Print #5, Rawdata(1, j, i); " , ";
    Next j
    Print #4, posdata(0, i); " , ";
    Print #4, posdata(1, i); " , ";
    Print #4, RawId$(i)
    Print #5, posdata(0, i); " , ";
    Print #5, posdata(1, i); " , ";
    Print #5, RawId$(i)
Next i
```

```
Close #4
Close #5

Rem now we need to do the background subtraction from rawdata and do it again
For i = 1 To NumSigs
   For j = 1 To NumIds
      If RawId$(i) = BakId$(j) Then
         For k = 1 To 7
            Rawdata(0, k, i) = Rawdata(0, k, i) - QBak(k, j) - QBak(0, j)
            Rawdata(1, k, i) = Rawdata(1, k, i) - IBak(k, j) - IBak(0, j)
            'MsgBox (Str(i) + " " + Str(k) + "  " + Str(Rawdata(1, k, i)) + "  " + Str(IBak(k,
j)) + "  " + Str(IBak(0, j)) + "  " + BakId$(j))
         Next k
      End If
   Next j
Next i

Rem write out the new files
Open f6$ For Output As #6
Open f7$ For Output As #7
For i = 1 To NumSigs
   For j = 1 To 7
      Print #6, Rawdata(0, j, i); " , ";
      Print #7, Rawdata(1, j, i); " , ";
   Next j
   Print #6, posdata(0, i); " , ";
   Print #6, posdata(1, i); " , ";
   Print #6, RawId$(i)
   Print #7, posdata(0, i); " , ";
   Print #7, posdata(1, i); " , ";
   Print #7, RawId$(i)
Next i
Close #6
Close #7
Form1.MousePointer = vbDefault

End Sub




Private Sub importit_Click()
End Sub

Private Sub Form_Load()

Rem this sets the area that is being processed.
'AreaNum = "1"
```

```
End Sub

Private Sub FragIt_Click()

If FragIt.Checked = False Then
   TarIt.Checked = False
   FragIt.Checked = True
   AllIt.Checked = False
   GphxIt.Checked = False
End If

End Sub

Private Sub GphxIt_Click()

If GphxIt.Checked = False Then
   TarIt.Checked = False
   FragIt.Checked = False
   AllIt.Checked = False
   GphxIt.Checked = True
End If

End Sub

Private Sub ingemittest_Click()
If AOneIt.Checked = True Then
   AreaNum = "1"
End If
If ATwoIt.Checked = True Then
   AreaNum = "2"
End If
If AThreeIt.Checked = True Then
   AreaNum = "3"
End If
If TarIt.Checked = True Then
   TVal = "T"
End If
If FragIt.Checked = True Then
   TVal = "F"
End If
If AllIt.Checked = True Then
   TVal = "A"
End If
If GphxIt.Checked = True Then
   TVal = "GT"
End If

cc = 1
```

```
CommonDialog1.FileName = "*.xyz"
CommonDialog1.Action = 1
Files$ = CommonDialog1.FileName
Rem get path
CommonDialog1.FileName = "*.txt"
'Msgbox (Files$)
Form1.MousePointer = vbHourglass
Rem These are all the filenames that are used
rawdataa$ = Files$
fl = Files$
histonames$ = "c:\windows\desktop\histonames" + AreaNum + ".txt"
wheredata$ = "C:\WINDOWS\Desktop\" + TVal + "where_" + AreaNum + "a_data.txt"
wheredata_vel$ = "C:\WINDOWS\Desktop\" + TVal + "where_" + AreaNum +
"a_data_vel.txt"
wheretarg$ = "c:\windows\desktop\" + TVal + "where_" + AreaNum + ".txt"
dposq$ = "C:\windows\desktop\hist_temp\" + TVal + "dpos_" + AreaNum +
"a_data_q.txt"
dposi$ = "C:\windows\desktop\hist_temp\" + TVal + "dpos_" + AreaNum +
"a_data_i.txt"

Tag_This = True
Rem fHandle = Hist_This()
Rem i am going to change hist_this to new_hist_this
Call new_hist_this
Rem Return from this routine is based on Tag_this
Rem if it is true then you have the histogram for the entire area file
Rem on the hard disk
Rem if it is false then you have the background
Rem histograms for the targets in target file
Rem and a file that has the signatures in the box defiend by dpos
Rem rem with and without background subtraction
Rem and a file that contains the maximum signature for all those found in dpos
Open wheredata$ For Output As #1
Open wheretarg$ For Input As #2
Open wheredata_vel$ For Output As #3
Rem this is the number of targets
Input #2, n
For i = 1 To n
   Rem for each target get the position and id name
   Input #2, eastval(i), northval(i), id$(i)
   icount = 1
   bb = 0
   Rem radius of search for background
   Rem we need to find the local background around that point
   Rem and we need to histogram it and write it out
   'dbk = 2.5
   dbk = CSng(Form1.Text4.Text)
   Rem radius of target maxima search
```

```
   'dpos = 0.25
   dpos = CSng(Form1.Text5.Text)
   'dbox = 0.5
   dbox = CSng(Form1.Text6.Text)
   Rem init postion holders
   nd = 0
   ed = 0
loopto:
      Rem p*d was the last position
      pnd = nd
      ped = ed
      Rem radial of last position
      pr = (pnd ^ 2 + ped ^ 2) ^ 0.5
      Rem posiition of item
      nd = posdata(0, icount)
      ed = posdata(1, icount)
      Rem for dx = zero make dth = 0 to avoid an error.
      dx = pnd - nd
      If dx = 0 Then
         dth = 0
      Else
         dth = Atn(dy / dx)
      End If
      dy = ped - ed
      ddr = (dx ^ 2 + dy ^ 2) ^ 0.5

      rnow = (nd ^ 2 + ed ^ 2) ^ 0.5
      If Abs(pr - rnow) > 0.025 Then
         'If nd < (northval(i) + dpos) And nd > (northval(i) - dpos) And ed < (eastval(i) +
dpos) And ed > (eastval(i) - dpos) Then
         '  For j = 1 To 14
         '     Print #1, Rawdata(0, j, icount); ",  "; Rawdata(1, j, icount); ",  ";
         '  Next j
         '  Print #1, ed; ",  "; nd; ", "; id$(i)
         'End If
         Rem this is selecting the area to look at
         Rem the problem has been that this area is where we are
         Rem trying to generate the maxima from and we have
         Rem cut out the target values
         Rem so the maxima is not there anymore

            'MsgBox ("first test")
            If nd < (northval(i) + dpos) And nd > (northval(i) - dpos) And ed < (eastval(i) +
dpos) And ed > (eastval(i) - dpos) Then
            'MsgBox (Str(northval(i) + dpos) + " " + Str(nd) + " " + Str(northval(i) - dpos)
+ " " + Str(eastval(i) + dpos) + " " + Str(ed) + " " + Str(eastval(i) - dpos))
            Rem this data goes to the maxima file and is a canidate for a valid signal
               For j = 1 To 14
                  Print #1, Rawdata(0, j, icount); ",  "; Rawdata(1, j, icount); ",  ";
```

```
            Next j
            Print #1, ed; ",  "; nd; ", "; id$(i)
            Print #3, ed; ",  "; nd; ", "; id$(i); " , "; dx; " , "; dy

          End If

          If nd < (northval(i) + dbk) And nd > (northval(i) - dbk) And ed < (eastval(i) +
dbk) And ed > (eastval(i) - dbk) And Not (nd < (northval(i) + dbox) And nd >
(northval(i) - dbox) And ed < (eastval(i) + dbox) And ed > (eastval(i) - dbox)) Then
            f5 = "C:\WINDOWS\Desktop\Hist_temp\" + TVal + "hist_where_" + id$(i)
+ ".txt"
            'MsgBox (f5 + " opened")
            Open f5 For Append As #5
            For j = 1 To 14
               Print #5, Rawdata(0, j, icount); ",  "; Rawdata(1, j, icount); ",  ";
            Next j
            Print #5, ed; ",  "; nd; ", "; id$(i)
            Close #5
          End If

        End If

    icount = icount + 1

    If icount <= jcount Then GoTo loopto
Next i
Close #3
Close #2
Close #1
'commenting out this part to speed up the output
'this is the part that does the individual histograming
Rem this is going to go away
Rem hist_this is going to become
Rem lochist_this and no global stuff will be there
Rem it will only deal with target items
'Tag_This = False
'fHandle = Hist_This()
Rem call lochist_this
Call lochist_this
Rem the histograms now exist
Rem the problem was that the maxima file had been written without the dpos box in the
data set
Rem I am now going to call a subprogram to create them
Rem it will be a variation of Hist_this
Rem but it will be called dpos_maxima
Call dpos_maxima
```

```
Form1.MousePointer = vbDefault
MsgBox ("search complete" + Chr(13) + "icount = " + CStr(icount) + Chr(13) + "jocunt
= " + CStr(jcount))
End Sub




Public Function Hist_This()
Rem the case of Tag_this true is the global histogram of the entire data set
Rem false is the local target case
If Tag_This = True Then
   Rem read off the header
   Open rawdataa$ For Input As #1
   For i = 1 To 30
      Input #1, head$(i)
   Next i
   Floop = 1
Else
   Floop = n
End If
For m = 1 To Floop
   If Tag_This = False Then
      Rem initalize variables for the local case
      Call initalizelocal
   End If
   icount = 0
   Rem find the extrema
   Call locateextrema
   If Tag_This = False Then
         Rem output maxima data for the local case
         Call localout
   End If
   jcount = icount
   Close #1
   Rem histogram in amplitude for each frequnecy and phase
   Call dohist
   Rem ********************
   Rem put out histogram for each
   Rem filenames are quadfl, infl, ...
   Rem get these names
   Rem for the global file
   If Tag_This = True Then
      Call globalhistout
   Else
      Call localhistout
```

```
   End If
Next m
End Function

Private Sub TarIt_Click()

If TarIt.Checked = False Then
   TarIt.Checked = True
   FragIt.Checked = False
   AllIt.Checked = False
   GphxIt.Checked = False
End If

End Sub

Private Sub toolit_Click()

End Sub
```

GridTool Program

```
Sub setscroll()
   LLIMIT = Form1.HScroll1.Value


   ULIMIT = Form1.HScroll2.Value

   ULIMIT = TX * LLIMIT / Form1.HScroll3.Max
   LLIMIT = TX * ULIMIT / Form1.HScroll2.Max
   If ULIMIT < LLIMIT Then
   dummy = LLIMIT
   LLIMIT = ULIMIT
   ULIMIT = dummy
   End If
   For i = LLIMIT To ULIMIT
   map(i) = RGB(75, 75, 75)
   Next i
End Sub



Sub GENCOLOR1()
WGC = 300
For i = 1 To TX
'
'r = 0.9 * 255 * (Exp(-((I - TX / 8) / WGC) ^ 2) + Exp(-((I - TX / 2) / WGC) ^ 2))
'g = 0.9 * 255 * (Exp(-((I - TX / 4) / WGC) ^ 2) + Exp(-((I - 5 * TX / 8) / WGC)
^ 2))
'b = 0.9 * 255 * (Exp(-((I - 3 * TX / 8) / WGC) ^ 2) + Exp(-((I - 7 * TX / 8) /
WGC) ^ 2))
'WGC = 250


'r = 1 * 255 * (Exp(-((I - 1 * TX / 16) / WGC) ^ 2) + Exp(-((I - 4 * TX / 16) /
WGC) ^ 2) + Exp(-((I - 7 * TX / 16) / WGC) ^ 2) + Exp(-((I - 10 * TX / 16) /
WGC) ^ 2) + Exp(-((I - 13 * TX / 16) / WGC) ^ 2))
'g = 1 * 255 * (Exp(-((I - 2 * TX / 16) / WGC) ^ 2) + Exp(-((I - 5 * TX / 16) /
WGC) ^ 2) + Exp(-((I - 8 * TX / 16) / WGC) ^ 2) + Exp(-((I - 11 * TX / 16) /
WGC) ^ 2) + Exp(-((I - 14 * TX / 16) / WGC) ^ 2))
'b = 1 * 255 * (Exp(-((I - 3 * TX / 16) / WGC) ^ 2) + Exp(-((I - 6 * TX / 16) /
WGC) ^ 2) + Exp(-((I - 9 * TX / 16) / WGC) ^ 2) + Exp(-((I - 12 * TX / 16) /
WGC) ^ 2) + Exp(-((I - 15 * TX / 16) / WGC) ^ 2))
' r = 1 * 255 * Exp(-((I) / WGC) ^ 2)
'g = 1 * 255 * Exp(-((I - TX / 2) / WGC) ^ 2)
'
'b = 1 * 255 * Exp(-((I - TX) / WGC) ^ 2)
```

```
'WGC = 75
'r = 0.9 * 255 * (Exp(-((I - TX / 8) / WGC) ^ 2) + Exp(-((I - TX / 2) / WGC) ^ 2))
'g = 0.9 * 255 * (Exp(-((I - TX / 4) / WGC) ^ 2) + Exp(-((I - 5 * TX / 8) / WGC)
^ 2))
'b = 0.9 * 255 * (Exp(-((I - 3 * TX / 8) / WGC) ^ 2) + Exp(-((I - 7 * TX / 8) /
WGC) ^ 2))

'WGC = 50

'
'r = 1 * 255 * (Exp(-((I - 1 * TX / 16) / WGC) ^ 2) + Exp(-((I - 4 * TX / 16) /
WGC) ^ 2) + Exp(-((I - 7 * TX / 16) / WGC) ^ 2) + Exp(-((I - 13 * TX / 16) /
WGC) ^ 2))
'g = 1 * 255 * (Exp(-((I - 2 * TX / 16) / WGC) ^ 2) + Exp(-((I - 5 * TX / 16) /
WGC) ^ 2) + Exp(-((I - 8 * TX / 16) / WGC) ^ 2) + Exp(-((I - 14 * TX / 16) /
WGC) ^ 2))
'b = 1 * 255 * (Exp(-((I - 3 * TX / 16) / WGC) ^ 2) + Exp(-((I - 6 * TX / 16) /
WGC) ^ 2) + Exp(-((I - 9 * TX / 16) / WGC) ^ 2) + Exp(-((I - 15 * TX / 16) /
WGC) ^ 2))
'map(I) = RGB(r, g, b)
'WGC = 20


'r = 1 * 255 * (Exp(-((I - 1 * TX / 32) / WGC) ^ 2) + Exp(-((I - 4 * TX / 32) /
WGC) ^ 2) + Exp(-((I - 7 * TX / 32) / WGC) ^ 2) + Exp(-((I - 10 * TX / 32) /
WGC) ^ 2) + Exp(-((I - 13 * TX / 32) / WGC) ^ 2) + Exp(-((I - 16 * TX / 32) /
WGC) ^ 2) + Exp(-((I - 19 * TX / 32) / WGC) ^ 2) + Exp(-((I - 22 * TX / 32) /
WGC) ^ 2) + Exp(-((I - 25 * TX / 32) / WGC) ^ 2) + Exp(-((I - 28 * TX / 32) /
WGC) ^ 2))
'g = 1 * 255 * (Exp(-((I - 2 * TX / 32) / WGC) ^ 2) + Exp(-((I - 5 * TX / 32) /
WGC) ^ 2) + Exp(-((I - 8 * TX / 32) / WGC) ^ 2) + Exp(-((I - 11 * TX / 32) /
WGC) ^ 2) + Exp(-((I - 14 * TX / 32) / WGC) ^ 2) + Exp(-((I - 17 * TX / 32) /
WGC) ^ 2) + Exp(-((I - 20 * TX / 32) / WGC) ^ 2) + Exp(-((I - 23 * TX / 32) /
WGC) ^ 2) + Exp(-((I - 26 * TX / 32) / WGC) ^ 2) + Exp(-((I - 29 * TX / 32) /
WGC) ^ 2))
'b = 1 * 255 * (Exp(-((I - 3 * TX / 32) / WGC) ^ 2) + Exp(-((I - 6 * TX / 32) /
WGC) ^ 2) + Exp(-((I - 9 * TX / 32) / WGC) ^ 2) + Exp(-((I - 12 * TX / 32) /
WGC) ^ 2) + Exp(-((I - 15 * TX / 32) / WGC) ^ 2) + Exp(-((I - 18 * TX / 32) /
WGC) ^ 2) + Exp(-((I - 21 * TX / 32) / WGC) ^ 2) + Exp(-((I - 24 * TX / 32) /
WGC) ^ 2) + Exp(-((I - 27 * TX / 32) / WGC) ^ 2) + Exp(-((I - 30 * TX / 32) /
WGC) ^ 2))
'WGC = 75
'r = 0.9 * 255 * (Exp(-((I - TX / 8) / WGC) ^ 2) + Exp(-((I - TX / 2) / WGC) ^ 2))
'g = 0.9 * 255 * (Exp(-((I - TX / 4) / WGC) ^ 2) + Exp(-((I - 5 * TX / 8) / WGC)
^ 2))
'b = 0.9 * 255 * (Exp(-((I - 3 * TX / 8) / WGC) ^ 2) + Exp(-((I - 7 * TX / 8) /
WGC) ^ 2))
WGC = 300
r = 0.9 * 255 * (Exp(-((i - TX / 5) / WGC) ^ 2))
```

```
g = 0.9 * 255 * (Exp(-((i - 3 * TX / 5) / WGC) ^ 2))
b = 0.9 * 255 * (Exp(-((i - 5 * TX / 5) / WGC) ^ 2))
map(i) = RGB(r, g, b)
Picture2.Line (i, 0)-(i, ty), map(i)
Next i
End Sub
Sub GENCOLOR2()

End Sub


Private Sub Command3_Click()

End Sub

Private Sub Command4_Click()


End Sub

Private Sub Command5_Click()


End Sub

Private Sub importit_Click()
End Sub

Private Sub Form_Load()

End Sub

Private Sub ingemittest_Click()
stuff = 0
cc = 1
CommonDialog1.FileName = "*.xyz"
maxspeed = 10000
CommonDialog1.Action = 1
Files$ = CommonDialog1.FileName
Rem get path
CommonDialog1.FileName = "*.txt"
Rem MsgBox (Files$)

f1$ = Files$
Text1.Text = Files$

TESTSET = Val(Text5.Text) - Val(Text4.Text)
Skip = True
skipto = Val(Text4.Text)
```

```
Open f1$ For Input As #1
  For i = 1 To 30
    Input #1, head$(i)
    'MsgBox (head$(i))

  Next i
  icount = 0
  BB = 0
  If Skip = True Then
    Skip = False

    For L = 1 To skipto
      For j = 1 To 14
        Input #1, Rawdata(1, j, icount), Rawdata(0, j, icount)
      Next j
      Input #1, posdata(0, icount), posdata(1, icount)
    Next L

  End If


Do While EOF(1) = False

  icount = icount + 1
  If icount > TESTSET Then GoTo getout




        For j = 1 To 14
          Input #1, Rawdata(1, j, icount), Rawdata(0, j, icount)
        Next j
        For j = 8 To 14
          If Rawdata(0, j, icount) < quadmin(j - 7) Then quadmin(j - 7) =
Rawdata(0, j, icount)
          If Rawdata(0, j, icount) > quadmax(j - 7) Then quadmax(j - 7) =
Rawdata(0, j, icount)
          If Rawdata(1, j, icount) < inmin(j - 7) Then inmin(j - 7) =
Rawdata(1, j, icount)
          If Rawdata(1, j, icount) > inmax(j - 7) Then inmax(j - 7) =
Rawdata(1, j, icount)
        Next j
          Input #1, posdata(0, icount), posdata(1, icount)
          If BB = 0 Then
            pos0max = posdata(0, icount)
            pos0min = posdata(0, icount)
            pos1max = posdata(1, icount)
            pos1min = posdata(1, icount)
```

```
        BB = 1
      End If
      If pos0max < posdata(0, icount) Then
        pos0max = posdata(0, icount)
        Label9.Caption = Str(pos0max)
      End If
      If pos0min > posdata(0, icount) Then
        pos0min = posdata(0, icount)
        Label10.Caption = Str(pos0min)
      End If
      If pos1max < posdata(1, icount) Then
        pos1max = posdata(1, icount)
        Label2.Caption = Str(pos1max)
      End If
      If pos1min > posdata(1, icount) Then
        pos1min = posdata(1, icount)
        Label1.Caption = Str(pos1min)
      End If
      If icount / 500 = Int(icount / 500) Then DoEvents



Loop
getout:

Close #1
Rem NOW WE DO THE HISTOGRAMS



'Open "C:\windows\desktop\pos_density.txt" For Output As #3
'di = 0.5
'dj = 0.5
'For j = pos1min To pos1max Step dj
  'For i = pos0min To pos0max Step di
    'numthere = 0
    'For k = 1 To icount - 1
    '   If posdata(0, k) > i And posdata(0, k) < (i + di) And posdata(1, k) > j
And posdata(1, k) < (j + di) Then numthere = numthere + 1
    'Next k
    ' DoEvents
    ' Label3.Caption = Str$(i)
    ' Label8.Caption = Str$(j)
    ' Label11.Caption = Str$(numthere)
    ' Print #3, numthere; " ";

  'Next i
  'DoEvents
```

```
  'Print #3, ""
'Next j



Picture2.ScaleMode = 3   ' Set ScaleMode to
Picture2.DrawWidth = 1  ' Set DrawWidth.
Picture2.ForeColor = QBColor(4)  ' Set background to red.
Picture2.Cls ' Clear form.
TX = Picture2.ScaleWidth
ty = Picture2.ScaleHeight

BB = 0
For LL = 1 To 7
  Call GENCOLOR1
DOITAGAIN:
  Label5.Caption = "FREQ " + Str$(LL)
    Picture1.BackColor = QBColor(0)
    Picture1.ScaleMode = 3   ' Set ScaleMode to
    Picture1.DrawWidth = 1  ' Set DrawWidth.
    Picture1.ForeColor = QBColor(4)  ' Set background to red.
    Picture1.Cls ' Clear form.
    dx = pos0max - pos0min
    dy = pos1max - pos1min
    sx = Picture1.ScaleWidth
    sy = Picture1.ScaleHeight
    dz = quadmax(LL) - quadmin(LL)
    Label6.Caption = Str$(quadmin(LL))
    Label7.Caption = Str$(quadmax(LL))
    Rem CLEAR HISVAL
    Picture3.ScaleMode = 3   ' Set ScaleMode to
    Picture3.DrawWidth = 1  ' Set DrawWidth.
    Picture3.ForeColor = QBColor(4)  ' Set background to red.
    Picture3.Cls ' Clear form.
    TX3 = Picture3.ScaleWidth
    TY3 = Picture3.ScaleHeight
    Rem ZEROHIST
    For i = 1 To TX3
    HISVAL(i) = 1
    Next i
    For i = 1 To TESTSET
      xx = sx * (posdata(0, i) - pos0min) / dx
      yy = sy - sy * (posdata(1, i) - pos1min) / dy
      ZZ = TX * (Rawdata(0, 7 + LL, i) - quadmin(LL)) / dz
      If ZZ < 0 Then ZZ = 1
      HISVAL(ZZ) = HISVAL(ZZ) + 1
      Picture1.PSet (xx, yy), map(ZZ)
      If i / 1000 = Int(i / 1000) Then DoEvents
    Next i
```

```
        HISTMAX = 1
        For i = 1 To TX3
        HISVAL(i) = Log(HISVAL(i))
        If HISTMAX < HISVAL(i) Then HISTMAX = HISVAL(i)
        Next i
        Label4.Caption = Exp(HISTMAX)
        For i = 1 To TX3
        YVAL = TY3 - Int(TY3 * HISVAL(i) / HISTMAX)
        Picture3.Line (i, YVAL)-(i, TY3), QBColor(0)
        DoEvents
        Next i
        DoEvents
        MsgBox ("search complete QUAD")
        Rem wait about 10 sec to set scroll bars
Next LL
Rem *********


Picture2.ScaleMode = 3   ' Set ScaleMode to
Picture2.DrawWidth = 1  ' Set DrawWidth.
Picture2.ForeColor = QBColor(4)  ' Set background to red.
Picture2.Cls ' Clear form.
TX = Picture2.ScaleWidth
ty = Picture2.ScaleHeight

BB = 0
For LL = 1 To 7
   Call GENCOLOR1

   Label5.Caption = "FREQ " + Str$(LL)
      Picture1.BackColor = QBColor(0)
      Picture1.ScaleMode = 3   ' Set ScaleMode to
      Picture1.DrawWidth = 1  ' Set DrawWidth.
      Picture1.ForeColor = QBColor(4)  ' Set background to red.
      Picture1.Cls ' Clear form.
      dx = pos0max - pos0min
      dy = pos1max - pos1min
      sx = Picture1.ScaleWidth
      sy = Picture1.ScaleHeight
      dz = inmax(LL) - inmin(LL)
      Label6.Caption = Str$(inmin(LL))
      Label7.Caption = Str$(inmax(LL))
      Rem CLEAR HISVAL
      Picture3.ScaleMode = 3   ' Set ScaleMode to
      Picture3.DrawWidth = 1  ' Set DrawWidth.
      Picture3.ForeColor = QBColor(4)  ' Set background to red.
      Picture3.Cls ' Clear form.
      TX3 = Picture3.ScaleWidth
      TY3 = Picture3.ScaleHeight
```

```
Rem ZEROHIST
For i = 1 To TX3
HISVAL(i) = 1
Next i
For i = 1 To TESTSET
   xx = sx * (posdata(0, i) - pos0min) / dx
   yy = sy - sy * (posdata(1, i) - pos1min) / dy
   ZZ = TX * (Rawdata(1, 7 + LL, i) - inmin(LL)) / dz
   If ZZ < 0 Then ZZ = 1
   HISVAL(ZZ) = HISVAL(ZZ) + 1
   Picture1.PSet (xx, yy), map(ZZ)
   If i / 1000 = Int(i / 1000) Then DoEvents
Next i
HISTMAX = 1
For i = 1 To TX3
HISVAL(i) = Log(HISVAL(i))
If HISTMAX < HISVAL(i) Then HISTMAX = HISVAL(i)
Next i
Label4.Caption = Exp(HISTMAX)
For i = 1 To TX3
YVAL = TY3 - Int(TY3 * HISVAL(i) / HISTMAX)
Picture3.Line (i, YVAL)-(i, TY3), QBColor(0)
DoEvents
Next i
DoEvents
MsgBox ("search complete in")
Rem wait about 10 sec to set scroll bars

Rem *******
'For LL = 1 To 7
'Label5.Caption = "FREQ " + Str$(LL)
 '  Picture1.ScaleMode = 3  ' Set ScaleMode to
  '  Picture1.DrawWidth = 1  ' Set DrawWidth.
   ' Picture1.ForeColor = QBColor(4)  ' Set background to red.
'   Picture1.Cls ' Clear form.
   'dx = pos0max - pos0min
   'dy = pos1max - pos1min
   'sx = Picture1.ScaleWidth
   'sy = Picture1.ScaleHeight
   'dz = inmax(LL) - inmin(LL)
   'Rem CLEAR HISVAL
   'For i = 1 To 1024
   'HISVAL(i) = 1
   'Next i
   'Label6.Caption = Str$(inmin(LL))
   'Label7.Caption = Str$(inmax(LL))
   'For i = 1 To TESTSET
      'xx = sx * (posdata(0, i) - pos0min) / dx
      'yy = sy - sy * (posdata(1, i) - pos1min) / dy
```

```
    'ZZ = TX * (Rawdata(1, 7 + LL, i) - inmin(LL)) / dz
    'HISVAL(ZZ) = ZZ + 1
    'Picture1.PSet (xx, yy), map(ZZ)
    'If i / 1000 = Int(i / 1000) Then DoEvents
  'Next i
  'Label4.Caption = Exp(HISTMAX)
  'For i = 1 To TX3
  'YVAL = TY3 - Int(TY3 * HISVAL(i) / HISTMAX)
  'Picture3.Line (i, YVAL)-(i, TY3), QBColor(0)
  'DoEvents
  'Next i
  'DoEvents
  'MsgBox ("search complete IN")
Next LL
End Sub

Private Sub matrixit_Click()

End Sub

Private Sub momatrit_Click()



End Sub

Private Sub noditherit_Click()


End Sub

Private Sub penit_Click()


End Sub

Private Sub rmatrit_Click()



End Sub

Private Sub toolit_Click()
Picture2.ScaleMode = 3   ' Set ScaleMode to
Picture2.DrawWidth = 1  ' Set DrawWidth.
Picture2.ForeColor = QBColor(4)  ' Set background to red.
Picture2.Cls ' Clear form.
TX = Picture2.ScaleWidth
ty = Picture2.ScaleHeight
```

```
WGC = 100
For i = 1 To TX

r = 0.9 * 255 * (Exp(-((i - TX / 8) / WGC) ^ 2) + Exp(-((i - TX / 2) / WGC) ^ 2))
g = 0.9 * 255 * (Exp(-((i - TX / 4) / WGC) ^ 2) + Exp(-((i - 5 * TX / 8) / WGC) ^
2))
b = 0.9 * 255 * (Exp(-((i - 3 * TX / 8) / WGC) ^ 2) + Exp(-((i - 7 * TX / 8) /
WGC) ^ 2))
WGC = 250


r = 1 * 255 * (Exp(-((i - 1 * TX / 16) / WGC) ^ 2) + Exp(-((i - 4 * TX / 16) /
WGC) ^ 2) + Exp(-((i - 7 * TX / 16) / WGC) ^ 2) + Exp(-((i - 10 * TX / 16) /
WGC) ^ 2) + Exp(-((i - 13 * TX / 16) / WGC) ^ 2))
g = 1 * 255 * (Exp(-((i - 2 * TX / 16) / WGC) ^ 2) + Exp(-((i - 5 * TX / 16) /
WGC) ^ 2) + Exp(-((i - 8 * TX / 16) / WGC) ^ 2) + Exp(-((i - 11 * TX / 16) /
WGC) ^ 2) + Exp(-((i - 14 * TX / 16) / WGC) ^ 2))
b = 1 * 255 * (Exp(-((i - 3 * TX / 16) / WGC) ^ 2) + Exp(-((i - 6 * TX / 16) /
WGC) ^ 2) + Exp(-((i - 9 * TX / 16) / WGC) ^ 2) + Exp(-((i - 12 * TX / 16) /
WGC) ^ 2) + Exp(-((i - 15 * TX / 16) / WGC) ^ 2))
 r = 1 * 255 * Exp(-((i) / WGC) ^ 2)
g = 1 * 255 * Exp(-((i - TX / 2) / WGC) ^ 2)

b = 1 * 255 * Exp(-((i - TX) / WGC) ^ 2)
WGC = 100
r = 0.9 * 255 * (Exp(-((i - TX / 8) / WGC) ^ 2) + Exp(-((i - TX / 2) / WGC) ^ 2))
g = 0.9 * 255 * (Exp(-((i - TX / 4) / WGC) ^ 2) + Exp(-((i - 5 * TX / 8) / WGC) ^
2))
b = 0.9 * 255 * (Exp(-((i - 3 * TX / 8) / WGC) ^ 2) + Exp(-((i - 7 * TX / 8) /
WGC) ^ 2))


map(i) = RGB(r, g, b)
Picture2.Line (i, 0)-(i, ty), map(i)
DoEvents


Next i

End Sub
```

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14. ABSTRACT

This report documents the analysis of the GEM-3 data collected for the Advanced UXO Detection/Discrimination Technology Demonstration at the U.S. Army Jefferson Proving Ground (JPG), Madison, IN. The analysis is funded through the 62720A/AF25 Program "301U-Subsurface UXO Detection and Discrimination" for Project "UXO03-Advance Sensor Data Analysis Techniques for Improved Buried Target Detection." The approach taken in the U.S. Army Engineer Research and Development Center's analysis of the performance of the GEM-3 at JPG was to extract data points collected near each of the actual target locations and compare them to the calibration data acquired with known targets at the beginning of the test. This was done to determine how well the data collected near each actual target matched the calibration signatures for the same ordnance type and the extent to which the data could be differentiated from other ordnance types of nonordnance clutter. Classification of the targets was performed using a simple template-matching algorithm. This procedure resulted in an exact classification match for nearly half of the targets for which calibration data were available and a match to a similarly sized target for more than two-thirds of the medium and large targets. The statistical variability of the measurements and the effect of ordnance depth on classification performance were also examined.

15. SUBJECT TERMS

Anomalies	Histogram	Spectroscopy
Calibration	Multifrequency	Target discrimination
Electromagnetic induction spectroscopy	Signatures	UXO

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